2019-12

# ASSESSING THE POTENTIAL VALUE OF AUTONOMOUS VEHICLES IN EMERGENCY MEDICAL SERVICES USING THE KNOWLEDGE VALUE ADDED METHODOLOGY

Hillhouse, Joseph S.

Monterey, CA; Naval Postgraduate School

http://hdl.handle.net/10945/64186

# NAVAL POSTGRADUATE SCHOOL

**MONTEREY, CALIFORNIA**

# THESIS

**ASSESSING THE POTENTIAL VALUE OF AUTONOMOUS VEHICLES IN EMERGENCY MEDICAL SERVICES USING THE KNOWLEDGE VALUE ADDED METHODOLOGY**

by

Joseph S. Hillhouse

December 2019

Co-Advisors: Thomas J. Housel
Richard D. Bergin IV

**Approved for public release. Distribution is unlimited.**

THIS PAGE INTENTIONALLY LEFT BLANK

| **REPORT DOCUMENTATION PAGE** | | | | *Form Approved OMB No. 0704-0188* |
|---|---|---|---|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503. | | | | |
| **1. AGENCY USE ONLY** ***(Leave blank)*** | **2. REPORT DATE** December 2019 | **3. REPORT TYPE AND DATES COVERED** Master's thesis | | |
| **4. TITLE AND SUBTITLE** ASSESSING THE POTENTIAL VALUE OF AUTONOMOUS VEHICLES IN EMERGENCY MEDICAL SERVICES USING THE KNOWLEDGE VALUE ADDED METHODOLOGY | | | | **5. FUNDING NUMBERS** |
| **6. AUTHOR(S)** Joseph S. Hillhouse | | | | |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** Naval Postgraduate School Monterey, CA 93943-5000 | | | | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
| **9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(E**S) N/A | | | | **10. SPONSORING / MONITORING AGENCY REPORT NUMBER** |
| **11. SUPPLEMENTARY NOTES** The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. | | | | |
| **12a. DISTRIBUTION / AVAILABILITY STATEMENT** Approved for public release. Distribution is unlimited. | | | | **12b. DISTRIBUTION CODE** A |

**13. ABSTRACT (maximum 200 words)**


Directors and fire chiefs throughout the emergency services are facing staffing shortages as emergency medical technicians and paramedics migrate to higher-paying, less-hazardous jobs in the medical field or emergency management environment. These shortages are compounded by a continually increasing service demand. This research compares the current “As Is” model in the multi-tiered, fire-based, advanced-life-support emergency medical system with the “To Be” model, which incorporates autonomous vehicle technologies. The two models were assessed using a knowledge value added (KVA) methodology to determine whether autonomous technology would increase productivity and add value by decreasing unit workload and increasing system capacity. The “As Is” model showed a return on knowledge (ROK) across all medical-based subprocesses but an inverse relationship between ROK and subprocess time, meaning that ROK drops when responders perform non-medical tasks and worsens the longer a subprocess takes. Moreover, driving is a poor use of the employee’s overall knowledge as ROK for driver subprocesses was as low as 38 percent during long transport times. The “To Be” model showed superior ROK across all variations of driver and most medical subprocesses, and all driver subprocesses showed exponential increases in ROK. This thesis finds that increased transport times and call volumes increase ROK in the “To Be” model, indicating a quantifiable value-add from autonomous technology.


| **14. SUBJECT TERMS** emergency medical service, EMS, advanced life support, ALS, basic life support, BLS, emergency medical technician, EMT, paramedic, fire service, multi-role responder, single role-responder, staffing levels, staffing shortages, National Fire Protection Association, NFPA, driver operator, emergency vehicle operations, knowledge value added, KVA, Lean Six Sigma, balanced scorecard, autonomous vehicles, hardware, software | | | **15. NUMBER OF PAGES** 101 |
|---|---|---|---|
| | | | **16. PRICE CODE** |
| **17. SECURITY CLASSIFICATION OF REPORT** Unclassified | **18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified | **19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified | **20. LIMITATION OF ABSTRACT** UU |

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

**Approved for public release. Distribution is unlimited.**

**ASSESSING THE POTENTIAL VALUE OF AUTONOMOUS VEHICLES IN EMERGENCY MEDICAL SERVICES USING THE KNOWLEDGE VALUE ADDED METHODOLOGY**

Joseph S. Hillhouse
Assistant Fire Chief, Gainesville Fire Rescue, Gainesville FL
BS, University of Florida, 2014

Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES**
**(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL**
**December 2019**

Approved by: Thomas J. Housel
Co-Advisor

Richard D. Bergin IV
Co-Advisor

Erik J. Dahl
Associate Professor, Department of National Security Affairs

THIS PAGE INTENTIONALLY LEFT BLANK

# ABSTRACT

Directors and fire chiefs throughout the emergency services are facing staffing shortages as emergency medical technicians and paramedics migrate to higher-paying, less-hazardous jobs in the medical field or emergency management environment. These shortages are compounded by a continually increasing service demand. This research compares the current “As Is” model in the multi-tiered, fire-based, advanced-life-support emergency medical system with the “To Be” model, which incorporates autonomous vehicle technologies. The two models were assessed using a knowledge value added (KVA) methodology to determine whether autonomous technology would increase productivity and add value by decreasing unit workload and increasing system capacity. The “As Is” model showed a return on knowledge (ROK) across all medical-based subprocesses but an inverse relationship between ROK and subprocess time, meaning that ROK drops when responders perform non-medical tasks and worsens the longer a subprocess takes. Moreover, driving is a poor use of the employee’s overall knowledge as ROK for driver subprocesses was as low as 38 percent during long transport times. The “To Be” model showed superior ROK across all variations of driver and most medical subprocesses, and all driver subprocesses showed exponential increases in ROK. This thesis finds that increased transport times and call volumes increase ROK in the “To Be” model, indicating a quantifiable value-add from autonomous technology.

THIS PAGE INTENTIONALLY LEFT BLANK

## TABLE OF CONTENTS

## LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

# LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ALS | advanced life support |
| APRL | avenue, place, road, lane |
| APU | all-purpose unit |
| ATC | average time to complete |
| AVF | augmented voltage foot |
| AMR | American Medical Response |
| BLS | basic life support |
| CAD | computer aided dispatch |
| DARPA | Defense Advanced Research Projects Agency |
| EMS | emergency medical service or emergency medical system |
| EMT | emergency medical technician |
| ETA | estimated time of arrival |
| EVOC | emergency vehicle operations course |
| FSFC | Florida State Fire College |
| IOT | internet of things |
| IV | intravenous |
| KVA | knowledge value added |
| LIDAR | light detection and ranging |
| LT | learning time |
| NFPA | National Fire Protection Association |
| NHTSA | National Highway Traffic Safety Administration |
| PPE | personal protective equipment |
| ROI | return on investment |
| ROK | return on knowledge |
| RRT | rapidly-exploring random tree |
| SME | subject matter expert |
| STD | street, terrace, drive |
| STEMI | S-T segment elevation myocardial infarction |
| TLTU | total learning time units |
| V2X | vehicle to everything |

THIS PAGE INTENTIONALLY LEFT BLANK

# EXECUTIVE SUMMARY

Emergency service leaders have been facing staffing shortages as emergency medical technicians and paramedics migrate to higher-paying, less-hazardous jobs in the medical field or emergency management environment. These staffing shortages have been compounded by a continually increasing service demand.

This thesis evaluated whether system automation could assist in augmenting staffing needs. Using a knowledge value added (KVA) methodology, the current “As Is” model in the multi-tiered, fire-based, advanced-life-support emergency medical system was compared to the “To Be” model, which incorporated autonomous vehicle technologies. The KVA methodology provided a quantitative assessment to compare the two models, which were evaluated based on the autonomous vehicles’ ability to increase productivity and system capacity.

The research showed a quantifiable increase in capacity and return on knowledge (ROK) in the “To Be” model. The author identified capacity and productivity as the measures of effectiveness. The “As Is” model showed ROK across all medical-based subprocesses. However, the model displayed an inverse relationship between ROK and subprocess time, meaning that ROK drops when responders preform non-medical tasks and worsens the longer a subprocesses takes. Moreover, driving is a poor use of an employee’s overall knowledge.

The “To Be” model showed superior ROK across all variations of driver and most medical subprocesses. Driver subprocesses showed exponential increases in ROK for all driver subprocesses, and this thesis finds that increased transport times and call volume increase ROK. Staffing changes afforded by automation allow one emergency medical service (EMS) unit to meet the two-paramedic optimization during transport. This effect increases the EMS unit capacity across the system and productivity in automated units. Specifically, only 1.63 units were required in the “To Be” model to accomplish the same work as two units in the “As Is” model.

Based on the research, once the technology maturates to readiness level 9 and autonomy level 5, autonomous vehicle implementation is suggested through the following steps:

1. Identification of a trial agency,
2. Installation of smart-city infrastructure,
3. Incorporation of emergency medical dispatch for call triage, if not present,
4. Delivery of an autonomous vehicle with all required software,
5. Training for responders on the software interface, and
6. Staffing of ambulances with two paramedics and one driver for safety during trial period.

ACKNOWLEDGMENTS

At NPS, I would like to thank my thesis advisors, Dr. Tom Housel and Richard Bergin, for their patience; my fellow classmates in CHDS cohorts 1803/1804 for setting great examples for me to follow; all my students who continue to ask questions that I don’t know the answers to and who fuel my passion for learning; and the CHDS faculty and staff for a quality program that makes our country better and safer!

In the fire service, I’d like to thank the leadership of the city of Gainesville, particularly Fire Chief Jeff Lane, for the support; the men and women of Gainesville Fire Rescue, who endured 16 years of me saying, “I just wrote a paper about that,” for their encouragement; the adjunct instructors and lab management of SFC EMS for picking up my slack, especially David Sutton, Danny Williams, Andrea Powell, Louis Mallory, and Mike Anderson.

Among my friends and family, I’d like to thank my parents for the love and work ethic they instilled in me; my father-in-law, Donald Onufer, for the calm words and encouragement; and the Durante family for their friendship and support. Last, and most importantly, I must thank my loving wife, Allison Hillhouse, for putting up with the past year and a half of absenteeism, weekends of me writing for days straight, and my reading in bed—and for her unwavering love and support.

> *Happy is the man who finds a true friend, and far happier is he who finds that true friend in his wife.*
>
> —Franz Schubert

THIS PAGE INTENTIONALLY LEFT BLANK

# I. INTRODUCTION

**R51:** "Rampart General Hospital, this is Neptune Fire Department Rescue 51."

**RGH:** "Go ahead, Rescue 51."

**R51:** "Rescue 51 is enroute code 3 with one rider from Engine 51. We have a 64-year-old male STEMI alert presenting with ST elevation in leads II, III, AVF, and V4R; now transmitting to you. Patient's chief complaint was chest pain, stated it felt like his last myocardial infarction. Pain was an eight on a scale of 10, now resolved after IV establishment with 500ml of normal saline, sublingual nitroglycerin administration x1, 50mcg of fentanyl, and 324mg of aspirin. Patient is positive for shortness of breath with clear and equal lung sounds. Vital signs: pulse 105, blood pressure 120/90, respiratory rate 22, and patient is showing sinus tachycardia on the monitor with a 99 percent SPO2 saturation. Rescue 51 ETA is five minutes."

**RGH:** "Rescue 51, STEMI alert confirmed. RGH has no questions or orders. Resuscitation Bay 5 on arrival."

**E51:** "Dispatch, this is Engine 51. We are out of service enroute to RGH for crew retrieval."

Across America, career, volunteer, combination, single, and multi-role emergency medical service (EMS) responders labor to meet the demands placed on them by increasing unit call loads and staffing shortages. On average, U.S. EMS providers respond to 27,825,983 requests for service each year.[1]

## A. THE PROBLEM

The problem is that the user demand for EMS services is increasing while staffing availability is decreasing. This is a problem because responder supply cannot meet the

[1] "EMS Data Cube," National Emergency Medical Services Information System, accessed October 9, 2019, https://rp.nemsis.org/reportportal/design/view.aspx.

growth of EMS demand, leading to unanswered calls and employee burnout. Without change, EMS staffing shortages will lead to system failure and unnecessary deaths.

Ambulance usage has been steadily rising throughout the country. Current EMS models are straining to meet user demand. A prevention report from the U.S. Centers for Disease Control and Prevention shows a 13 percent increase in ambulance transports between 1997 and 2006.[2] The 18.4 million ambulance transports in 2006 accounted for 15.4 percent of total emergency-room admissions.[3] Between 1997 and 2018, there was a 100 percent increase in emergency calls, the majority of which were for EMS.[4] These trends mean that the call load from 1997 to 2018 doubled nationwide with no predicted end to the growth.

There is a growing national trend of EMS staffing shortages.[5] One reason is the high industry turnover rate.[6] The average emergency medical technician (EMT) spends roughly five years on the job before moving on to hospital employment, nursing, medical school, emergency management, or a career entirely outside EMS.[7] In 2011, the *Emergency Medical Services Workforce Agenda for the Future* identified workforce shortages as EMS employers' largest concern.[8] In early 2019, American Medical Response (AMR), a private EMS services provider, reported paying overtime wages to regular staff,

---

[2] International Association of Fire Chiefs, *Handbook on Mobile Integrated Healthcare* (Chantilly, VA: International Association of Fire Chiefs, 2017), 11, https://www.iafc.org/docs/default-source/1ems/iafchandbookformih.pdf?sfvrsn=aa44b30d_0.

[3] International Association of Fire Chiefs, 11.

[4] "Fire Department Calls," National Fire Protection Association, last modified November 2019, https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Fire-department-calls.

[5] "Solutions: Who We Help," American Medical Response, accessed December 6, 2019, https://www.amr.net/solutions.

[6] Kate Snyder, "Ambulance Services Face National Paramedic Shortage," EMS1, March 28, 2019, https://www.ems1.com/paramedic-jobs-and-careers/articles/393665048-Ambulance-services-face-national-paramedic-shortage/.

[7] Maranda Faris, "As Medicine, Nursing Careers Call, Fewer People Want to Work on EMS Crews in Western Tennessee," *Jackson Sun*, July 14, 2017, https://www.jacksonsun.com/story/news/local/2017/07/14/addressing-ems-shortages/467507001/.

[8] Susan Chapman, Vanessa Lindler, and Jennifer Kaiser, *The Emergency Medical Services Workforce Agenda for the Future* (Washington, DC: National Highway Traffic Safety Administration, 2011), 26, https://www.ems.gov/pdf/2011/EMS_Workforce_Agenda_052011.pdf.

bringing in crews from other parts of the state, and at times, taking office staff and administrators away from their regular jobs because of paramedic and EMT shortages.[9] AMR even tried recruiting from outside its contract areas by offering bonuses and relocation packages to EMTs from Florida, Georgia, the Carolinas, and other states.[10]

Given the increasing EMS call loads, EMS worker shortages, and resource-intensive calls, EMS could use an innovative solution to address these industrywide concerns.

## B. PURPOSE

For most calls, the severity cannot be accurately determined, leading to over-triage and the dispatching of multiple EMS units to meet the two-paramedic optimization in the event of critical patients. Multiple EMS units' being needlessly tied up decreases the system's reserve capacity. In other words, two EMS units may be dispatched and unavailable serving someone who has called 9-1-1 with cold symptoms when a traumatic accident requires them right down the road. The practice of sending multiple EMS units when two paramedics are needed is sub-optimal, and this over-triage and inefficiency is potentially costing lives.

Current philosophies on ambulance optimization include staffing one advanced life support supervisor/attendant and one basic life support driver.[11] Autonomous vehicles may be one way to increase capacity and decrease the workload of current employees. By allowing the entire crew to focus on medical care rather than driving, the two-paramedic optimization could be met by one ambulance staffed with two paramedics. By using autonomous vehicles, agencies could decrease the number of EMS units—unit demand—

---

[9] Faris, "Fewer People Want to Work on EMS Crews.

[10] Kristi Nelson, "Emergency Wait: Local Ambulance Crews Face Challenges with Crowded ERs, EMT Shortage," *Knoxville News Sentinel*, January 9, 2019, https://www.knoxnews.com/story/news/health/2019/01/09/ambulances-wait-times-hospitals-crowded-ers-emt-shortages/2514188002/.

[11] David Shotwell, Mark Merlin, and Vincent Robbins, "Ambulance Crew Configuration: Are Two Paramedics Better Than One?," JEMS, October 8, 2018, https://www.jems.com/2018/10/08/ambulance-crew-configuration-are-two-paramedics-better-than-one/.

needed per call from two units to one for stable patients and only one unit during transport even when the patient is unstable.

This thesis measures the effect of replacing the human driver with an autonomous vehicle that will decrease unit demand using a knowledge value added (KVA) methodology. KVA analysis identifies inputs, processes, and outputs in common units, creating a "common reference frame" for comparison.[12] This common reference frame allows the researcher to calculate the effect on productivity, i.e., output/input, using the return on knowledge (ROK) ratio that measures the effectiveness of utilization of knowledge assets, whether human or automated.[13]

The purpose of this study is to explore the potential of autonomous vehicles to add value and optimize EMS system capacity and productivity. This study is not designed as a staffing study and is not focused or designed to answer questions regarding appropriate department staffing or reducing staff. However, it may provide some insights into the future when there is a move to use autonomous emergency vehicles.

## C. BACKGROUND

For the current research context, EMS is defined by the Florida Administrative Code as "any entity licensed in the state of Florida to provide air, or ground ambulance, whether Basic Life Support (BLS) provider or an Advanced Life Support (ALS) provider, and whether a non-transportation or a transportation service."[14] An EMS unit is defined as an appropriately equipped and state-licensed vehicle, minimally staffed to respond to either ALS or BLS emergencies.

There are many models used in the emergency services. A uniform EMS model is one that sends the same type and number of resources to all EMS calls, is always at the

[12] Jose Cintron, "A Framework for Measuring the Value-Added of Knowledge Processes with Analysis of Process Interactions and Dynamics" (PhD diss., University of Central Florida, 2013), 16, http://stars.library.ucf.edu/cgi/viewcontent.cgi?article=3739&context=etd.

[13] Scott H. LaRocca, "Knowledge Value Added (KVA) Methodology as a Tool for Measuring the Utilization of Knowledge Assets aboard Marine Corps Installations" (master's thesis, Naval Postgraduate School, 2008), https://calhoun.nps.edu/handle/10945/4118.

[14] Fla. Admin. Code 64J-1 (2019), https://www.flrules.org/gateway/ChapterHome.asp?Chapter=64J-1.

ALS level, and always includes a transport-capable unit.[15] A fire-based, multi-role EMS system is one in which employees are cross-trained and certified in both fire and EMS, and providers operate from existing fire stations.[16] Unlike the uniformed model, a tiered response model dispatches either an ambulance or a non-transport ALS/BLS unit based on the caller's answers to scripted questions from the dispatcher.[17] In a tiered response model, the 9-1-1 dispatcher rapidly elicits signs and symptoms from the caller for medical categorization.[18] The result of this "dispatcher triage" is the optimal configuration of responders for a specific emergency rather than, for example, only ALS units or both transport and non-transport units on all cases.

The National Fire Protection Association (NFPA) recommends that ALS emergencies receive a minimum of two paramedics.[19] This staffing level is consistent with a 2014 study showing better patient survival rates when two paramedics treat the patient.[20] If the two-paramedic recommendation is met by staffing one ambulance with two paramedics, optimization is lost when one paramedic on the crew of two has to drive. To overcome this loss, many EMS agencies use a multi-tiered system of response incorporating a fire-based EMS unit staffed with a crew of two to four multi-role responders, including one paramedic. If the patient is stable, the crew turns patient care over to an ambulance. If the patient is unstable, the fire crew augments the ambulance crew,

---

[15] David Persse and Katarzyna Kimmel, "Background and Advantages of a Tiered EMS Response in a Large, Fire-Based EMS Model," *Health Care: Current Reviews* 3, no. 1 (2015), https://doi.org/10.4172/2375-4273.1000138.

[16] Rob Frampton, "Company Officer Leadership: Fire-Based EMS Systems," International Association of Fire Chiefs, May 4, 2017, https://www.iafc.org/on-scene/on-scene-article/company-officer-leadership-fire-based-ems-systems.

[17] Persse and Kimmel, "Background and Advantages of a Tiered EMS Response," 1.

[18] Jeff J. Clawson, "EMS Dispatch," *Anesthesia Key* (blog), June 14, 2016, https://aneskey.com/ems-dispatch/.

[19] National Fire Protection Association, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, NFPA 1710 (Quincy, MA: National Fire Protection Association, 2016), https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1710.

[20] Nicholas M. Eschmann et al., "The Association between Emergency Medical Services Staffing Patterns and Out-of-Hospital Cardiac Arrest Survival," *Prehospital Emergency Care* 14, no. 1 (January 2010): 71–77, https://doi.org/10.3109/10903120903349820.

and both vehicles go to the hospital. This protocol increases overall unit demand, increases workload, and decreases system capacity.

How does the 9-1-1 system work? For this thesis, the EMS response continuum was sub-divided into three phases: input, process, and output. This description is important because if the desired outcome may be achieved without the process, then there is no value added by the process itself.

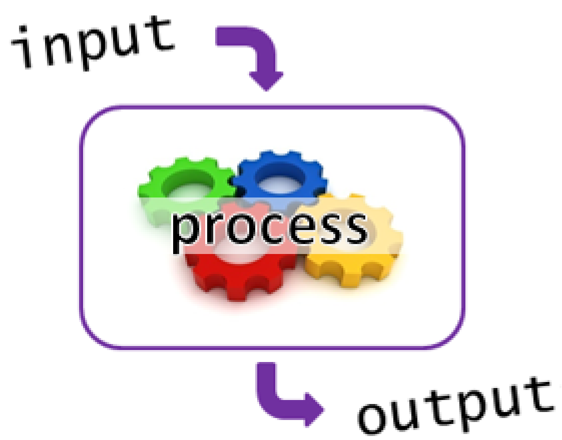
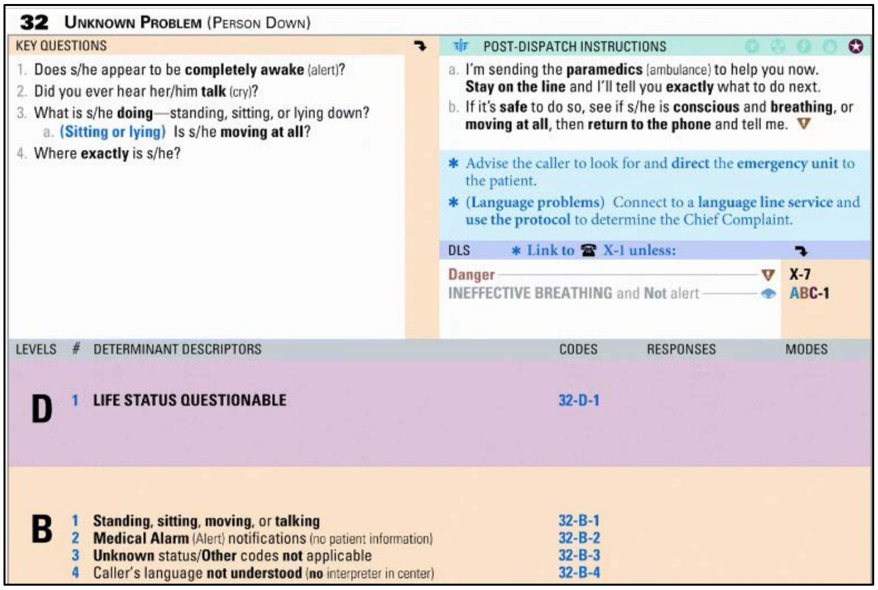



Figure 1. Input, Process, Output Illustration[21]

In the input phase, 9-1-1 dispatch answers and triages the call and dispatches emergency units. Once the public safety answering point receives a call, the telecommunicator, using emergency medical dispatch software, answers the 9-1-1 caller and asks a series of scripted questions aimed at efficiently triaging the level of the emergency for a tiered response.[22] Figure 2 shows a dispatch algorithm for a "person down" with an unknown problem.

[21] Source: "Input-Process-Output," 101 Computing, May 14, 2018, https://www.101computing.net/original-price-calculator/input-process-output/.

[22] "Emergency Medical Dispatch (EMD)," Association of Public-Safety Communications Officials International, accessed December 7, 2019, https://www.apcointl.org/training-and-certification/disciplines/emergency-medical-dispatch-emd/.



32 UNKNOWN PROBLEM (PERSON DOWN)

KEY QUESTIONS

1. Does s/he appear to be **completely awake** (alert)?
2. Did you ever hear her/him **talk** (cry)?
3. What is s/he **doing**—standing, sitting, or lying down?
   a. (Sitting or lying) Is s/he **moving at all**?
4. Where **exactly** is s/he?

POST-DISPATCH INSTRUCTIONS

a. I'm sending the **paramedics** (ambulance) to help you now. **Stay on the line** and I'll tell you **exactly** what to do next.
b. If it's **safe** to do so, see if s/he is **conscious** and **breathing**, or **moving at all**, then **return to the phone** and tell me.

* Advise the caller to look for and **direct** the **emergency unit** to the patient.
* **(Language problems)** Connect to a **language line service** and **use the protocol** to determine the Chief Complaint.

DLS * Link to X-1 unless:

Danger — X-7
INEFFECTIVE BREATHING and Not alert — ABC-1

| LEVELS | # | DETERMINANT DESCRIPTORS | CODES | RESPONSES | MODES |
|---|---|---|---|---|---|
| D | 1 | LIFE STATUS QUESTIONABLE | 32-D-1 | | |
| B | 1 | **Standing**, **sitting**, **moving**, or **talking** | 32-B-1 | | |
| | 2 | **Medical Alarm** (Alert) notifications (no patient information) | 32-B-2 | | |
| | 3 | **Unknown** status/**Other** codes **not** applicable | 32-B-3 | | |
| | 4 | Caller's language **not understood** (no interpreter in center) | 32-B-4 | | |

Figure 2. Emergency Medical Dispatch Example[23]

The questions initially verify the address and determine the nature and severity of the emergency. Once this baseline information has been obtained, computer aided dispatch (CAD) software, using a response matrix, queries automatic vehicle locators and recommends to the radio operator which units to dispatch. The telecommunicator remains on the phone with the caller, gaining more information and entering it into the call notes section of the dispatch software until the caller hangs up the phone or EMS units arrive on scene.

Next, the radio operator receives the recommendations from CAD and approves them for dispatch. Once all selected units verify their response, the radio operator updates the responders by summarizing information entered in the call notes by the telecommunicator. The radio operator continues to monitor the responding crews during response, treatment, and transport for safety, further communication, and resource needs.[24] Figures 2 and 3 illustrate the complexity of the dispatch process and possibility of over- or under-triage in a multi-tier system.

[23] Source: Clawson, "EMS Dispatch."

[24] "Job Duties of 911 Dispatchers," 911 Dispatcher EDU, accessed December 7, 2019, https://www.911dispatcheredu.org/job-description/.

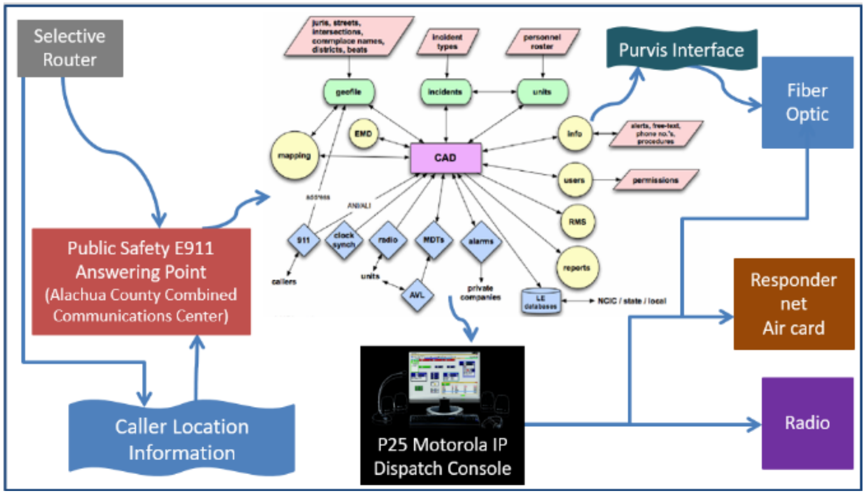



Figure 3. Computer Aided Dispatch Flowchart[25]

During the process phase, emergency units respond, treat, and/or transport the patient. This thesis divides the process phase into 11 subprocesses: (1) mapping the location, (2) determining the route, (3) readying the vehicle, (4) navigating, (5) piloting the vehicle to the call, (6) developing a differential diagnosis, (7) stabilizing treatment, (8) piloting the vehicle to the hospital, (9) continuing treatment, (10) transferring the patient to definitive care, and (11) documenting the response.

The ambulance driver receives the initial page from CAD and, using one's emergency vehicle operation course (EVOC) training, maps the location, determines the best route to take, and makes the vehicle ready to depart. Once responding, the ambulance driver may use one's medical knowledge only peripherally and may not participate in the preparation of equipment or donning of personal protective equipment (PPE) as one's focus must be on safely piloting the vehicle. On scene, the ambulance driver may use one's medical training to assist in developing a differential diagnosis and medically stabilizing the patient. However, the driver must abandon the vehicle to do so. This means there is no one for vehicle security or to reposition the vehicle for the best departure angle. During transport, the ambulance driver once again cannot use one's medical training at all,

[25] Adapted from "Computer Aided Dispatch Flowchart," Purvis, accessed September 1, 2019, https://www.purvis.com/what-we-do/fire-station-alerting/.

focusing entirely on piloting the vehicle. Finally, the patient is unloaded, a verbal report is given, and the report is documented. Here, the driver may resume medical duties to assist the paramedic in patient turn-over. The output phase represents the patient being passed on to definitive care as appropriate.

The response continuum outlines the workflow of the telecommunicator, radio operator, and ambulance driver. This structure is used in parallel throughout the thesis to allow uniformed interpretation during KVA analysis.

## D. LITERATURE REVIEW

This literature review covers three bodies of work: methods for measuring value to an organization; EMS scope, operational models, and changing paradigms; and rationalizations for and arguments against autonomous vehicle adoption.

### 1. Measuring Technology Value

To measure the value of the knowledge required to perform the tasks of each of the subprocesses—including the tasks an EMS driver must learn and the value of an autonomous vehicle technology designed to replace the knowledge of the driver—it is necessary to demonstrate how value is measured in the KVA methodology.

In business, leaders must manage a portfolio of strategic investment options, e.g., in employees, machinery, automation, infrastructure. These executives require a method for portfolio optimization decisions, to wit, a way to compare all investment options. The KVA methodology provides a means to translate various outputs into common units of output by examining inputs, processes, and resulting aggregate outputs. Think, for example, of the computer language of the operating system as the knowledge required by the system to produce the appropriate determined outputs. In business, many aggregate methods are used to measure value at the whole organizational level. The most common methods include Lean Six Sigma, balanced scorecard, and KVA.

Lean Six Sigma’s strength lies in reducing waste to improve profitability. Six Sigma cuts production costs, improves quality, speeds up production, helps organizations stay competitive, and saves money.[26] According to Ankit Rastogi, a certified Lean Six Sigma black belt, “Lean focuses on saving money for the company by focusing on the types of waste and how to reduce the waste.”[27] Furthermore, as Salman Taghizadegan, a leading “master black belt” points out, Lean Six Sigma is based on four success factors: choosing the right process, ensuring the right participants, conducting management reviews, and sustaining the gain and improvement.[28] This makes Lean Six Sigma good at optimizing incremental change and stabilizing processes at the nominal level. However, Lean Six Sigma is agnostic to technology and does not provide a common unit of output description, making productivity metrics problematic because the focus is on cost, i.e., the denominator of the output/input ratio.

A more holistic approach to business value measurement is the balanced scorecard method. In contrast to the Lean Six Sigma approach, Khim Ling Sim, assistant professor of accountancy at Western New England College, believes that, too often, the focus is on traditional performance measures such as “financial- and functional-level performance.”[29] Instead, Sim advocates for a “balanced scorecard” of measures. The balanced scorecard communicates the strategies businesses are trying to accomplish and aligns work with their strategic plans. Unlike Lean Six Sigma, which focuses on short-term productivity improvements through cost cutting, the balanced scorecard approach evaluates four strategic categories presumed to affect corporate performance: learning and growth, internal business processes, the customer, and financial outcomes.[30] Although, or because, the balanced scorecard uses multiple measures, it lacks a common unit-value reference for

[26] Ankit Rastogi, “A Brief Introduction to Lean, Six Sigma and Lean Six Sigma,” Grey Campus, March 12, 2018, https://www.greycampus.com/blog/quality-management/a-brief-introduction-to-lean-and-six-sigma-and-lean-six-sigma.

[27] Rastogi.

[28] Salman Taghizadegan, *Mastering Lean Six Sigma: Advanced Black Belt Concepts* (New York: Momentum Press, 2013), 4, ProQuest.

[29] Hian Chye Koh and Khim Ling Sim, “Balanced Scorecard: A Rising Trend in Strategic Performance Measurement,” *Measuring Business Excellence* 5, no. 2 (2001): 18–27, https://doi.org/10.1108/13683040110397248.

[30] Koh and Sim, “Balanced Scorecard.”

the four variables, with the exception of financial metrics. However, financial metrics that require a value estimate only operate at the whole corporation level of aggregation.

Lean Six Sigma and the balanced scorecard can create positive and measurable results; however, both processes are difficult to apply when the process has yet to be defined or the output is more intangible, and neither provides a common unit of value metric at the sub-corporate or process level. The inherent difficulties with measuring the value of intangibles led Tom Housel and Valerie Kanevsky to create the KVA methodology.[31] Kannan and Akhilesh agree that KVA's intangible accounting techniques allow managers to conduct "business process audits."[32] Kannan and Akhilesh caution, "Managers need a behavioral tool to understand the factors that influence human capital knowledge value add, in order to increase the organizational value add."[33] This requirement for a behavioral tool is meant to help managers focus on and forecast how various approaches to motivate employees might affect productivity. However, to measure the impacts of these approaches, managers require a common unit of value metric, such as that supplied by the KVA methodology, to gauge the relative impact on productivity of various motivational approaches.

### 2. EMS: A State-of-the-Union Overview

In short supply are scholarly articles or reports that discuss the national staffing shortage or increasing workloads of EMS providers. One National Highway Traffic Safety Administration (NHTSA) report alludes to why these topics are found only in trade journals and blogs: EMS systems across the country are not uniform, and they deviate in type, funding, service level, and call volume—and even whether the service is paid, volunteer,

---

[31] Thomas J. Housel and Valery Kanevsky, "Measuring the Value Added of Management: A Knowledge Value Added Approach," NPS-AM-06-056 (Monterey, CA: Naval Postgraduate School, December 31, 2006), 3, https://doi.org/10.21236/ADA496651.

[32] Gopika Kannan and K. B. Akhilesh, "Human Capital Knowledge Value Added: A Case Study in Infotech," *Journal of Intellectual Capital* 3, no. 2 (2002): 167–79, https://doi.org/10.1108/14691930210424752.

[33] Kannan and Akhilesh.

or a combination thereof.[34] This diversity makes EMS difficult to study as a system. What is apparent from the research is that, over time, the role and professional standards of EMS responders have changed to more closely align with social services and hospital programs. This alignment has led to competing markets vying for EMTs and paramedics. This "workers' market" has contributed to the current and expanding staffing shortages experienced by EMS agencies, which is why EMS needs to look at automation to help alleviate the problem.

During the genesis of EMS, many government-based EMS models set response standards at the national best practices of two paramedics and two EMTs for unstable patients. Over time, the changing scope and use of EMS has contributed to competing markets for the same workforce. A 1966 white paper that identified trauma as "the neglected disease of modern society" was crucial in establishing the need for and scope of EMS and prompted multiple congressional acts.[35] By highlighting the disparate survival outcomes between injured war fighters in Vietnam and traumatic injuries by U.S. civilians, this paper gave Congress its first quantitative look at trauma statistics in the United States.[36] Propelled by this discussion, Congress enacted the National Highway Safety Act of 1966.[37] This act was followed by the Emergency Medical Services Systems Act of 1973, which created more than 300 EMS systems nationwide through funding.[38] This early paper and the corresponding legislation provided the blueprints for modern EMS and remained the guiding documents from 1973 to the mid-90s.

---

[34] "EMS Research," National Highway Traffic Safety Administration, accessed December 7, 2019, https://www.ems.gov/research.html.

[35] National Research Council, *Accidental Death and Disability: The Neglected Disease of Modern Society* (Washington, DC: National Research Council, 1966), https://www.ems.gov/pdf/1997-Reproduction-AccidentalDeathDissability.pdf.

[36] National Research Council.

[37] Joshua Bucher and Hashim Zaidi, "A Brief History of Emergency Medical Services in the United States," Emergency Medicine Residents' Association, accessed February 9, 2019, http://www.emra.org/about-emra/history/ems-history/.

[38] Emergency Medical Services Systems Act, Pub. L. No. 93–154, S. 2410, 93rd Cong. (1973).

In 1996, the NHTSA published a document outlining the EMS agenda for the future that remained the guiding document in the industry until 2010.[39] This agenda described the core curriculum, scope of practice, and certification of EMS professionals.[40] This national standard moved EMS workers from fractioned jobs to a national profession. Once EMS became a nationally recognized profession, EMS leaders began adjusting their service models to include not only their trauma emergency roots but other needs of the community as well. This re-scoping of EMS emerged from open discussions between professional organizations and industry writers, like Skip Kirkwood, rather than from one definitive white paper as in the past.[41] This new direction for EMS has been described as "EMS 2.0" and focuses on mobile integrated healthcare, incorporating EMS into a holistic healthcare approach.[42]

Along with scoping, EMS literature also includes a discussion about operational models. One of the largest contributors to this discussion is the NFPA, which produces operational standards through an open consensus process. For example, NFPA 1710 outlines the *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*.[43] NFPA 1451 provides a training standard for fire and emergency service vehicle operations.[44] Together, these two standards form best practice recommendations on staffing EMS vehicles and driver training, which in many cases have been adopted into federal or state law.

---

[39] National Highway Traffic Safety Administration, *Emergency Medical Services Agenda for the Future* (Washington, DC: National Highway Traffic Safety Administration, 1996), https://one.nhtsa.gov/people/injury/ems/agenda/emsman.html.

[40] National Highway Traffic Safety Administration.

[41] "Skip Kirkwood," Journal of Emergency Management Services, accessed March 17, 2019, https://www.jems.com/authors/q-t/skip-kirkwood-ms-jd-emt-p-efo.html.

[42] Kelly Grayson, "EMS 2.0: The Logistics of Change," EMS1, March 11, 2010, https://www.ems1.com/archive/articles/ems-20-the-logistics-of-change-yqzT26TIxusme7Gk/.

[43] National Fire Protection Association, NFPA 1710, 1.

[44] National Fire Protection Association, *Standard for a Fire and Emergency Service Vehicle Operations Training Program*, NFPA 1451 (Quincy, MA: National Fire Protection Association, 2018), https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1451.

Beyond the quantitative consensus standards established by the NFPA is the subjective discussion of who should be providing emergency medical services. An International Association of Fire Fighters white paper advocates for a fire-based EMS system that leverages multi-role responders rather than single-role, EMS-only responders.[45] This view has been echoed by many trade organizations, including the Congressional Fire Service Institute, the International Fire Chiefs Association, the Metropolitan Fire Chiefs Association, and the International Fire Service Training Association.[46] However, this view contrasts those of single-role EMS providers and professional organizations, such as the National Association of EMTs, which advocate for a standalone EMS.[47] In support of single-role providers, the NHTSA goes as far as calling for a stand-alone federal EMS agency within the Department of Homeland Security, separate from the United States Fire Administration.[48]

### 3. Autonomous Vehicle Technology: Advocates and Detractors

There is a gap in the research because autonomous vehicles are not currently being used in the EMS although they are being tested in other areas such as trucking and ride-share services such as Uber. However, the strengths of autonomous vehicle technology, such as precision, speed, and safety, show great promise for EMS integration. According to the NHTSA,

---

[45] Franklin D. Pratt et al., *Prehospital 9-1-1 Emergency Medical Response: The Role of the United States Fire Service in Delivery and Coordination* (Washington, DC: International Association of Fire Fighters, July 5, 2007), https://services.prod.iaff.org/ContentFile/Get/17079.

[46] International Association of Fire Fighters, "Fire Service-Based EMS Electronic Tool Kit" (Washington, DC: International Association of Fire Fighters, 2013), https://www.nfpa.org/-/media/Files/Membership/member-sections/Metro-Chiefs/FSBased-EMS-Tool-Kit-2013.ashx?la=en.

[47] Mac Kemp, "EMS and Homeland Security," *Homeland Security Affairs*, June 10, 2014, https://www.hsaj.org/articles/262.

[48] "IAFF Opposes Creation of Separate EMS Administration," International Association of Fire Fighters, accessed February 9, 2019, https://www.fireengineering.com/articles/2005/06/iaff-opposes-creation-of-separate-ems-administration.html.

> Preventing significant numbers of crashes will, in addition to relieving the enormous emotional toll on families, also greatly reduce the enormous related societal costs—lives lost, hospital stays, days of work missed, and property damage—that total in the hundreds of billions of dollars each year. Moreover, these dramatic changes will offer significant new opportunities for investments in the underlying technologies and employment in the various industries that develop, manufacture, and maintain them.[49]

Many vehicle developers with autonomous-like options, such as Elon Musk, have written about autonomous vehicles as disruptive technology that will eventually lead to non-autonomous vehicles being illegal.[50] Brindel defines disruptive technology as "an innovation that uproots an established technology, or a revolutionary product or service that spawns a new industry."[51] Autonomous vehicles are a disruptive technology with numerous positive and negative homeland security implications such as those explored during this research. However, it is important to review both the challenges and opportunities before any steps are taken to automate EMS vehicles.

The autonomous vehicle "race" began when the Defense Advanced Research Projects Agency (DARPA) first recruited designers to create autonomous vehicles. The goal was for autonomous vehicles to replace humans in many hazardous military operations such as supply convoys.[52] In a long-term effort to speed up the development of the technology necessary for autonomous vehicles, capable of replacing humans in hazardous conditions, DARPA held a first of its kind challenge. The Grand Challenge engaged the wider research community, tapping into its collective ingenuity by offering a prize of $1 million. The goal was for vehicles to navigate autonomously through a 142-

[49] National Highway Traffic Safety Administration, "Preliminary Statement of Policy Concerning Automated Vehicles" (Washington, DC: National Highway Traffic Safety Administration, 2013), https://itlaw.wikia.org/wiki/Preliminary_Statement_of_Policy_Concerning_Automated_Vehicles.

[50] Sarah Alender, "Elon Musk Thinks Cars You Can Drive Might Be Outlawed Someday," *Wall Street Insanity* (blog), March 18, 2015, https://wallstreetinsanity.com/elon-musk-thinks-cars-you-can-drive-might-be-outlawed-someday/.

[51] Beth Brindel, "What's a Disruptive Technology?," How Stuff Works, November 1, 2014, https://electronics.howstuffworks.com/everyday-tech/what-is-disruptive-technology.htm.

[52] Matthew Williams, "The Drive for Autonomous Vehicles: The DARPA Grand Challenge," Herox, accessed December 7, 2019, https://www.herox.com/crowdsourcing-news/159-the-drive-for-autonomous-vehicles-the-darpa-grand.

mile desert course starting in Barstow, California, and ending in Primm, Nevada.[53] On March 13, 2004, 15 vehicles started the challenge, but none finished, and the prize went unclaimed.[54] From these fledgling beginnings, both the technology and DARPA's collaborative process for success began to flourish. Two additional challenges were held for autonomous vehicles with the proverbial bar being raised after each one. The third competition, the Urban Challenge in 2007, pitted driverless vehicles navigating through a staged city environment in Victorville, California.[55] To increase the complexity, vehicles had to contend with other moving traffic and obstacles and were required to obey traffic regulations. Eleven teams attempted the challenge, but only six were successful in completing the course.[56] Points were awarded based on the vehicles' ability to obey California driving rules and total time to complete the course. Carnegie Mellon University's Tartan Racing Team took home the $2 million prize. Based on the success of the Grand Challenge program, DARPA currently has three additional challenges in communications, robotics, and automated network defense. Since then, the technology has advanced and evolved to take on, or change, many well-established industries like hotels and airlines. Today, there are over 28 different companies manufacturing autonomous vehicles.[57]

Literature on the technical aspects of autonomous vehicles can be broken into two categories: hardware and software. The literature on hardware describes the technical aspects of the technology. For instance, Sam Huang explains how variations in autonomy

---

[53] "The DARPA Grand Challenge: Ten Years Later," Defense Advanced Research Projects Agency, March 13, 2014, https://www.darpa.mil/news-events/2014-03-13.

[54] Defense Advanced Research Projects Agency, "The DARPA Grand Challenge"; Alex Davies, "Inside the Races That Jump-Started the Self-Driving Car," *Wired*, November 10, 2017, https://www.wired.com/story/darpa-grand-urban-challenge-self-driving-car/.

[55] Davies.

[56] John Voelcker, "Autonomous Vehicles Complete DARPA Urban Challenge," IEEE Spectrum, November 1, 2007, https://spectrum.ieee.org/transportation/advanced-cars/autonomous-vehicles-complete-darpa-urban-challenge.

[57] Jason Marks, "What Software Do Autonomous Vehicle Engineers Use? Part 1/2," *Medium* (blog), June 25, 2018, https://medium.com/@olley_io/what-software-do-autonomous-vehicle-engineers-use-part-1-2-275631071199.

are achieved.[58] Despite the competitive nature of the autonomous vehicle industry, the body of work on software shows that common software languages have emerged that allow some interoperability.[59]

Now that the "how" seems within reach, supporters and detractors have emerged on both sides of the "should we" question relating to autonomous vehicles. Those in favor of the technology include venture capitalists and early adopters who believe the technology will benefit society overall through increased safety. Proponents cite more efficient roads, decreased traffic fatalities, and less litigation from DUIs and traffic incursions. Elon Musk, founder of Tesla, compares autonomous vehicles to the evolution of the elevator.

For autonomous vehicle usage to become ubiquitous, the industry must prepare the infrastructure and overcome those attempting to discredit the technology. Not everyone is for autonomous vehicles, and their addition to the driving landscape will not be without challenge. Autonomous vehicle supporters, like Musk, challenge that non-autonomous vehicles may one day be illegal. However, autonomous vehicle detractors, like writer Justin Westbrook of the online periodical Jalopnik, point out that it is currently illegal to operate autonomous vehicles fully autonomously. This means that both sides will have the ability to present their arguments in the judicial and political realm. Traditionalists and realists comprise the naysayers. For instance, a study conducted by the Massachusetts Institute of Technology found that less than 50 percent of consumers were interested in autonomous vehicles.[60] Comparative studies of other autonomous technology in the airline industry showed that safety margins decreased during initial adoption.[61] This has led detractors, like Peter Hancock, who believes replacing human control must be approached mindfully, to

---

[58] Sam Huang, "How the Autonomous Car Works: A Technology Overview," *Medium* (blog), April 25, 2018, https://medium.com/@thewordofsam/how-the-autonomous-car-works-a-technology-overview-5c1ac468606f.

[59] Marks, "What Software Do Autonomous Vehicle Engineers Use?"

[60] Zenajor Enwemeka, "Consumers Don't Really Want Self-Driving Cars, MIT Study Finds," WBUR Boston, May 25, 2017, https://www.wbur.org/bostonomix/2017/05/25/mit-study-self-driving-cars.

[61] Peter Hancock, "Are Autonomous Cars Really Safer Than Human Drivers?," *Scientific American*, February 3, 2018, https://www.scientificamerican.com/article/are-autonomous-cars-really-safer-than-human-drivers/.

write about the psychology of automation. Hancock believes human replacement has more effects than a simple one-for-one swap.

#### 4. Conclusion

Prior research has examined the genesis of EMS, which is going through a change in identity and service delivery models. EMS workers are choosing different environments in which to practice their craft, such as hospitals and doctors' offices. These two changes are driving staffing shortages. Meanwhile, autonomous vehicle technology is advancing. What was not explored in the literature review were the second- and third-order consequences of autonomous vehicle integration or how much control humans psychologically should concede to automation.

### E. RESEARCH QUESTIONS

1. How does the use of autonomous vehicles effect EMS process capacity?

2. What is the impact of autonomous vehicles on EMS process productivity?

For this thesis, capacity is measured as a function of the number of ALS units required to meet the two-paramedic optimization recommended for unstable ALS patients by NFPA 1710. This metric speaks to the efficiency of the system. Productivity is measured as a function of ROK and speaks to system redundancy and resilience.

This research explores the potential of autonomous vehicles to add value by optimizing EMS system capacity and decreasing workload. This study is not designed as a staffing study nor is it focused or designed to answer questions regarding appropriate staffing or reducing staff.

### F. DESIGN/METHODS

This thesis provides an exploratory comparison of emergency vehicle drivers in the "As Is" model to the value-add in the "To Be" model, which includes autonomous vehicles designed to replace the driving function. The KVA methodology is used to compare changes in the relative productivity of the various subprocesses in the "As Is" and "To Be" models.

### 1. Historical Procedures

Historical data populated the "As Is" model, and projections from these baseline data were used to forecast the potential value-added contributions of autonomous vehicles in the "To Be" model.[62]

To investigate the minimum training requirements and role of the emergency vehicle driver, the following Boolean parameters were used for database search criteria: Florida Bureau of EMS, emergency medical technician, EMT, paramedic, EMT-B, EMT-I, EMT-P, EMT + training, paramedic + training, EMT + curriculum, paramedic + curriculum, emergency vehicle driver, ambulance driver, Emergency Vehicle Operations Course, EVOC, VFIS + EVOC, NFPA + driver training, Florida Rule 64J, and Florida Statute 401.

To investigate how autonomous vehicles work and to ensure a like comparison between the "As Is" and "To Be" models, the following Boolean parameters were used for database search criteria: autonomous vehicles, What are autonomous vehicles capable of?, machine learning, AI, AGI, LIDAR, Tesla, autonomous vehicle software, autonomous vehicle hardware, and autonomous vehicle + ethics.[63]

### 2. Descriptive Procedures

To establish the "As Is" model, a waterfall framework was used to create a representative example of emergency vehicle driver "job data" for ambulance driver operators/driver engineers in medium-sized "metro" departments in the state of Florida. To create a representative example, the researcher began with minimum state requirements and industry standards, such as NFPA recommendations.

Next, to establish a realistic model of emergency driver training, a survey was created to elicit a subject matter expert (SME) consensus of the learning time in the "As Is" model. Two SMEs were used for comparison. Training and requirements for driver operators/driver

[62] The data collection began with an exhaustive literature review via the Dudley Knox Library at the Naval Postgraduate School, the National Emergency Training Center Library at the National Fire Academy, and the George A. Smathers Library System at the University of Florida. Additionally, the author performed internet searches and reviewed periodicals, books, journals, government training, and policy manuals.

[63] Zotero was used to collect, organize, and analyze research.

engineers were solicited from Alachua County Fire Rescue and Lakeland Fire Department. Of the nine questions posed to the SME agencies, the SMEs responded identically or alike to five questions, with variations in terminology interpreted by the researcher. The remaining four questions asked specifically about agency policies. To ensure a good sample correlation, a T-score was calculated from the responses. A large T-score indicates that the groups are different, and a small T-score indicates that they are similar.[64] To calculate a T-score, the researcher valuated "yes/like" answers as 1 and "no/different" answers as 2. Question 9, which dealt with starting pay, was removed from the T-score calculation. As shown in Table 1, a T-value of 0.3 was achieved from the driver survey.

Table 1. Driver Survey Sample Correlation

| Driver survey sample correlation | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Question** | **Yes/like (1)** | **No/diff (2)** | | **Deviation Score** | | | **Square of deviation score** | | | | **Sample Varience** | |
| | ACFR | **Lakeland** | | ACFR | **Lakeland** | | ACFR | **Lakeland** | | **Cross Products** | ACFR | **Lakeland** |
| **1** | 1 | **1** | | -0.125 | **-0.25** | | 0.015625 | **0.0625** | | **0.000976563** | 0.109375 | **0.1875** |
| **2** | 1 | **2** | | -0.125 | **0.75** | | 0.015625 | **0.5625** | | **0.008789063** | | **Correlation** |
| **3** | 1 | **1** | | -0.125 | **-0.25** | | 0.015625 | **0.0625** | | **0.000976563** | | **Coefficient** |
| **4** | 1 | **2** | | -0.125 | **0.75** | | 0.015625 | **0.5625** | | **0.008789063** | | **3.314E+18** |
| **5** | 1 | **1** | | -0.125 | **-0.25** | | 0.015625 | **0.0625** | | **0.000976563** | | **T-Value** |
| **6** | 1 | **1** | | -0.125 | **-0.25** | | 0.015625 | **0.0625** | | **0.000976563** | | **0.3251073** |
| **7** | 1 | **1** | | -0.125 | **-0.25** | | 0.015625 | **0.0625** | | **0.000976563** | | |
| **8** | 2 | **1** | | 0.875 | **-0.25** | | 0.765625 | **0.0625** | | **0.047851563** | | |
| **9** | 33321.60 | **58478.53** | | 33320.48 | **58477.28** | | 1110254054 | **3419592276** | | **3.79662E+18** | | |
| **Mean** | 1.125 | 1.25 | **Sum** | 0 | 0 | **SS** | 0.875 | 1.5 | **Sum** | 3.79662E+18 | | |

To ensure reliability, the researcher used the following questions, outlined by Fowler in *Survey Research Methods*, as a guide to create the survey:

- Are questions consistently understood?
- Do respondents have the information needed to answer the questions?
- Do the answers accurately describe what respondents have to say?
- Do the answers provide valid measures of what the question is designed to measure?[65]

---

64 Will Kenton, "T-Test Definition," Investopedia, accessed November 2, 2019, https://www.investopedia.com/terms/t/t-test.asp.

65 Floyd Fowler, *Survey Research Methods*, 4th ed. (Thousand Oaks, CA: SAGE Publications, 2009), 6, https://doi.org/10.4135/9781452230184.

### 3. Survey Questions

Answers to the following questions were aggregated to produce an accurate “As Is” model for comparison.

1. Does your agency operate a fire-based EMS model?

2. Does your agency have ambulances?

3. What is the minimum staffing (number of people, regardless of provider level) on ambulances for your agency?

4. Is the driver of the ambulance required to be fire certified?

5. Is the ambulance driver a promoted or entry level position in your department?

6. In your department, what is the minimum medical training required for an ambulance driver to maintain employment, i.e., complete probation, e.g., first responder, EMT, or paramedic?

7. In your department, what are the minimum driver training requirements for an ambulance driver? Choose all that apply:

    - In-house training meeting State requirements of rule 64J
    - Additional, above the State minimum, in-house training, e.g., driver orientation or promotional classes
    - EVOC certification
    - Florida State Fire College (FSFC) Apparatus Operations
    - FSFC Hydraulics
    - FSFC Aerial Operations

8. If you answered yes to question 7, “additional, above the State minimum, in-house training,” how many hours are required? If you previously answered in the negative, please enter zero.

9. What is the starting pay for an ambulance driver in your department?

#### 4. Experimental Procedures

The researcher populated data fields from the historical and descriptive research, as previously mentioned, and defined variables required for KVA comparison, such as yearly resource cost, the number of employees performing a subprocess, learning time, the average hourly cost per subprocess, subprocess times performed in a year, and the average time to complete the subprocess. These constants and variables were then used to graph results with varying call volumes and transport times using the following equation:

Monetized ROK = ((Total Learning Time Units or TLTU * (Process Price Surrogate per Year/Summed TLTU))/Process Cost per Year

Table 2. Volume/Transport Punnett Square

| | Short Transport | Long Transport |
|---|---|---|
| **High Volume** | HVST | HVLT |
| **Low Volume** | LVST | LVLT |

These results were used to answer the research questions:

1. How does the use of autonomous vehicles effect EMS process capacity?

2. What is the impact of autonomous vehicles on EMS process productivity?

## G. HYPOTHESES/ CONTEXT LIMITATIONS

It is the hypothesis of the researcher that crew augmentation by autonomous vehicles will show a value-add vis-à-vis the medical knowledge of the EMT or second responder being deployable throughout the entire call continuum. Additionally, the knowledge added by the automation should increase redundancy and resiliency during driver-related subprocesses.

This study was limited by the large variety of available models, jurisdictional compositions, and crew configurations. The sheer volume of EMS deployment models made a single industry standard unattainable. One representative model was created for comparison. Numerous models were found just in Florida. Models included ALS, BLS, uniformed, multi-tiered, single-role, multi-role, professional, paid on call, volunteer, and combination departments.

Additionally, the geographical and available resource make-up of the response area also presents different challenges and made comparisons difficult. For instance, a rural agency with limited resources covering 1,100 square miles with no secondary or tertiary care facilities in the jurisdiction and a 45-minute transport time will have different challenges than a resource-heavy agency covering a single municipality of 110 square miles with multiple tertiary care facilities in the jurisdiction and a five-minute transport time.

Finally, the researcher limited crew configurations to EMT or paramedic. Other states and countries use nurses, physician assistants, nurse practitioners, and doctors to staff ambulances. The ROK versus return on investment (ROI) of alternate practitioners was not explored.

THIS PAGE INTENTIONALLY LEFT BLANK

# II. RESULTS

## A. HISTORICAL RESULTS: THE DRIVER/EMT (AS IS)

The emergency vehicle driver/EMT not only is responsible for the vehicle but also must function as a member of the medical crew. This duality requires increased training, selection, and flexibility on the part of the emergency vehicle driver.

### 1. Medical Requirements

The entry-level course into the EMS realm is for the first responder. In Florida, all law enforcement, fire, and EMS providers are required to be certified first responders and meet the requirements of the U.S. Department of Transportation's Emergency Medical Services First Responder Training Course.[66] The emergency medical responder's scope of practice includes simple lifesaving interventions desigend to assist critical patients while awaiting higher-level practicioners.[67] This certification can be accomplished through a first responder or emergency medical responder (EMR) course. The course may be taught in a one-week, 40–60 hour format or in a one-semester format through local colleges.

Certification as an EMT is required for minimal staffing levels of ALS vehicles. The EMT's scope of practice encorporates non-invasive skills focused on stabilizing and transporting critical and emergent patients. EMTs differ from paramedics in that EMTs are allowed to perform non-invasive skills such as bleeding control, splinting, oxygen administration, and insertion of a supraglottic airway.[68] For an emergency medical technician, a training program "approved by the department as equivalent to the most recent EMT-Basic National Standard Curriculum or the National EMS Education Standards of the United States Department of Transportation" is required.[69]

---

[66] Fla. Stat. §112.1815 (2014), https://www.flsenate.gov/Laws/Statutes/2014/112.1815.

[67] National Highway Traffic Safety Administration, *National EMS Scope of Practice Model* (Washington, DC: National Highway Traffic Safety Administration, 2007), 29–31, https://www.ems.gov/education/EMSScope.pdf.

[68] National Highway Traffic Safety Administration, 29–31.

[69] Fla. Stat. § 401.27 (2012), http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&URL=0400-0499/0401/Sections/0401.27.html.

The paramedic scope of practice includes invasive skills such as intravenous (IV) and intraosseous (IO) fluid replacement, IV medication administration, needle decompression of the chest, pericardiocentesis, and surgicial cricothyrotomy.[70] For a paramedic, a “nationally accredited Paramedic program that meets all other State requirements” is required.[71]

Medical training times were derived from Florida’s adaptation of the EMS scope-of-practice model. The researcher found that minimum requirements were 300 hours for an EMT; however, the requirement increased throughout the state and between public and private institutions.[72] For this thesis, medical training hours include 40 hours for first responders and 400 hours for EMTs, for a total of 440 hours. Additional training is required for the advanced scope of the paramedic. For this thesis, 1,100 hours of training is used for certification as a paramedic, for a total of 1,540 hours.[73]

#### 2. Driver Requirements

Being the driver and a medical crew member requires a plethora of skills. Emergency vehicle driver training for the state of Florida is outlined in state statute § 401.281 and Rule 64J-1.013, Drivers.[74] Each driver must complete at least 16 hours of course instruction on driving a emergency vehicle, including classroom and behind-the-wheel training.[75]

#### 3. Selection

Beyond the minimum requirements, one metro department from the survey required the driver to be a promoted position with minimum years of service. Personnel

---

[70] National Highway Traffic Safety Administration, *National EMS Scope of Practice Model*, 29–31.

[71] National Highway Traffic Safety Administration, *Agenda for the Future*, 28.

[72] Fla. Admin. Code § 64J-1.013 (2008), https://www.flrules.org/gateway/ruleNo.asp?id=64J-1.013; Fla. Admin. Code § 64J-1.020 (2019), https://www.flrules.org/gateway/ruleNo.asp?id=64J-1.020.

[73] Fla. Admin. Code § 64J-1.020.

[74] Fla. Stat. § 401.281 (2019), http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0400-0499/0401/Sections/0401.281.html; Fla. Admin. Code § 64J-1.013.

[75] Fla. Admin. Code § 64J-1.013.

selection is critical in developing an effective emergency vehicle driver program.[76] Some of the criteria recommended for consideration in driver selection include, age, health, and psychological readiness.[77]

## B. EMS AUTONOMOUS VEHICLE INTEGRATION (TO BE)

In the "To Be" EMS model, the autonomous vehicle takes over all vehicle piloting and navigation. This automation will allow both crew members to focus solely on patient care, decreasing crew workload.

So how do autonomous vehicles work? The United States currently has semi-autonomous vehicles operating. Some of these cars adjust speed, brake automatically, or parallel park themselves, and this technology is widely accepted. Before fully autonomous cars and trucks integrate onto U.S. roads, they must progress through six "driver assistance technology levels."[78] The levels range from no automation, requiring an engaged driver, to fully autonomous, in which human drivers are never required to take control to safely operate the vehicle (see Figure 4).[79]

---

[76] Volunteer Firemen's Insurance Service, "Emergency Vehicle Operations Course" (York, PA: Volunteer Firemen's Insurance Service, 2009), 39.

[77] Volunteer Firemen's Insurance Service, 41.

[78] "Automated Vehicles for Safety," National Highway Traffic Safety Administration, accessed December 7, 2019, https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.

[79] National Highway Traffic Safety Administration.

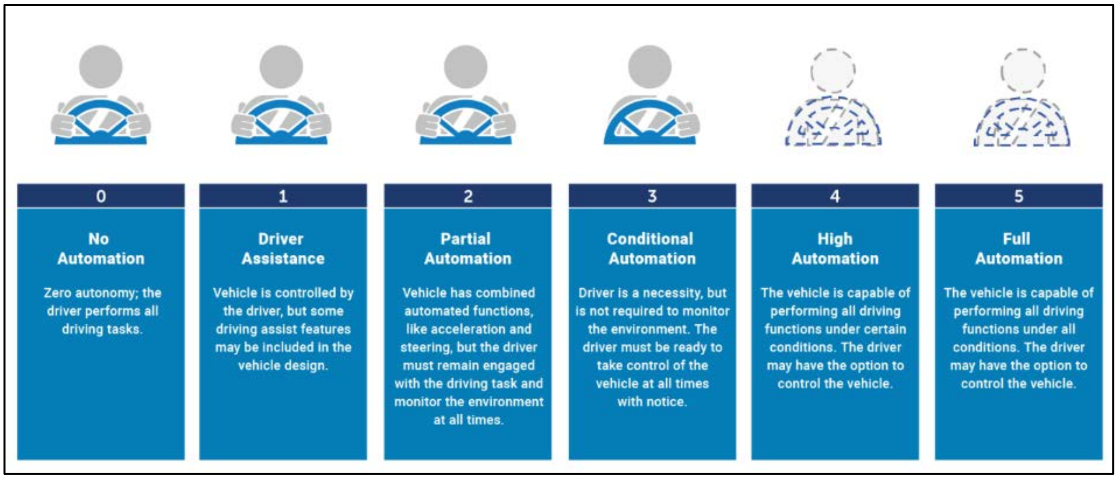



Figure 4. Vehicle Autonomy Levels[80]

Autonomous or "driverless" cars combine onboard hardware, including sensors and actuators, to control, navigate, and drive the vehicle with software for perception, planning, and control.[81] One advantage of autonomous vehicles is their ability to safely maneuver through tight spaces with unwavering accuracy.

### 1. Hardware

Although many processes have been explored, the first step in vehicle automation is for vehicles to create and maintain an internal map. Tesla uses a computer vision–based vehicle detection technology. Tesla cars use a software system known as "Autopilot" to analyze the surrounding environment.[82] Through "computer vision," also known as sophisticated image recognition, Autopilot uses high-tech cameras to collect and process data about its surroundings. These data are then interpreted to assist in decision making.[83]

---

[80] Source: National Highway Traffic Safety Administration, "Automated Vehicles for Safety."

[81] "Self-Driving Cars Explained," Union of Concerned Scientists, February 21, 2018, https://www.ucsusa.org/clean-vehicles/how-self-driving-cars-work.

[82] Neal E. Boudette, "Tesla Upgrades Autopilot in Cars on the Road," *New York Times*, September 23, 2016, https://www.nytimes.com/2016/09/24/business/tesla-upgrades-autopilot-in-cars-on-the-road.html.

[83] "How Do Self-Driving Cars Work?," *IoT for All* (blog), October 1, 2018, https://www.iotforall.com/how-do-self-driving-cars-work/.

In this aspect, Autopilot drives more like a person would. Tesla's technology and vehicles are available on the market now.

Other autonomous vehicle manufacturers, such as Google's Waymo, use hardware such as light detection and ranging (LIDAR). LIDAR uses "pulsed lasers" that emit a light capable of measuring the exact distance to objects.[84] LIDAR creates precise three-dimensional maps showing the shape, direction, speed, and surface characteristics of objects. See LIDAR equipment placement in Figure 5.

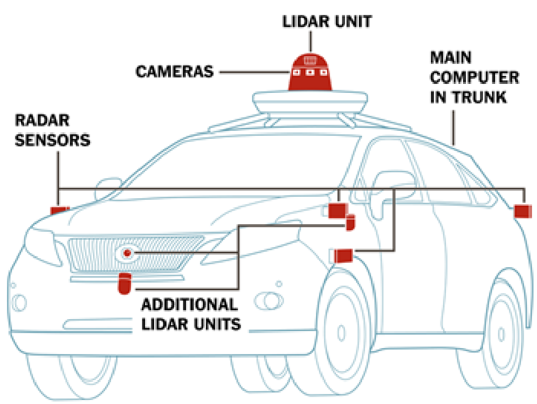



Figure 5. Autonomous Vehicle Hardware[85]

To get the full benefit of automated vehicles, smart cars need the ability to communicate with the surrounding infrastructure. Vehicle to everything (V2X) is the umbrella term for the vehicle's communication system tying information from onboard and environmental sensors via high-bandwidth, low-latency, high-reliability links.[86] This is accomplished through a wide array of sensors and internet of things (IoT) technology. IoT

84 "What Is LIDAR?," National Oceanic and Atmospheric Administration, accessed December 7, 2019, https://oceanservice.noaa.gov/facts/lidar.html.

85 Source: "How Driverless Cars See the World around Them," *New York Times*, March 19, 2018, https://www.nytimes.com/2018/03/19/technology/how-driverless-cars-work.html.

86 "What Is Vehicle-to-Infrastructure (V2I) Communication and Why Do We Need It?," 3M, accessed December 7, 2019, https://www.3m.com/wps/portal/en_US/3M/road-safety-us/resources/road-transportation-safety-center-blog/full-story/~/what-is-vehicle-to-infrastructure-v2i-communication-and-why-do-we-need-it/?storyid=021748d7-f48c-4cd8-8948-b7707f231795.

is the connecting of any device with an on and off switch to the internet and/or each other.[87] Smart Infrastructure can communicate updates pertaining to sharp curves, traffic jams, crashes, and speeds based on weather, road, and traffic conditions. Smart infrastructure includes advanced road markings, pavement lane markings, smart signs, and retroreflective signs that are visible in all driving conditions to both machine and human drivers. Smart infrastructure assists autonomous vehicles with faster decision making and more accurate navigation.[88] Additionally, wireless communication that connects directly with vehicles will allow the speedy identification of construction zones and potential safety hazards, such as someone walking with a smart phone. Currently, competing hardware infrastructure is vying for V2X superiority, which could be a good thing for safety and redundancy. These V2X sensors fall broadly into four categories: vehicle-to-pedestrian cars talking to smartphones, vehicle-to-vehicle cars talking with other cars, vehicle-to-infrastructure cars talking to traffic lights and parking spaces, and environment-to-vehicle cars talking to data centers (see Figure 6).[89]

---

87 Jacob Morgan, "A Simple Explanation of 'the Internet of Things,'" *Forbes*, May 13, 2014, https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/.

88 3M, "What Is Vehicle-to-Infrastructure (V2I) Communication?"

89 Huang, "How the Autonomous Car Works."

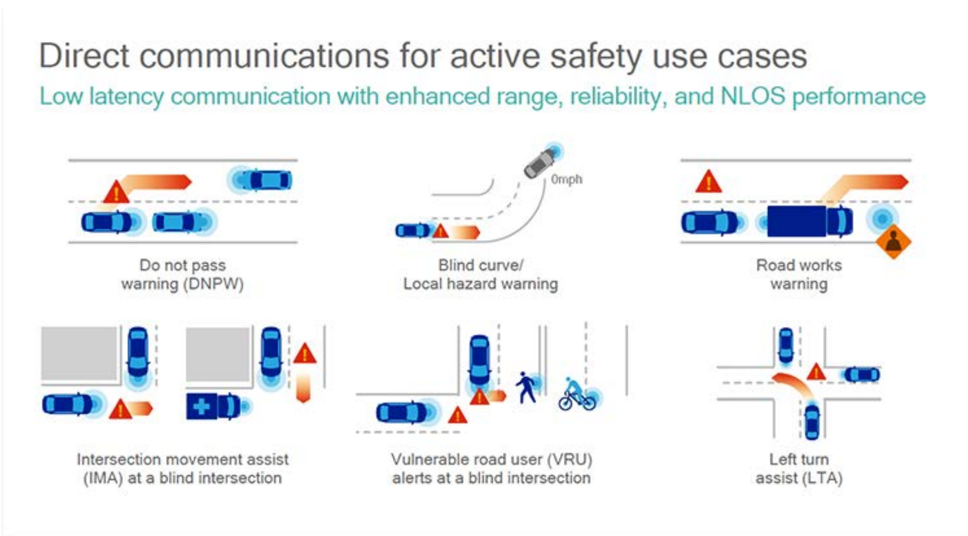



Figure 6. Smart Infrastructure Examples[90]

### 2. Software

The autonomous vehicle excels in its ability to plan effective routes and safely, dispassionately negotiate traffic, regardless of the call type. The software is the brains of the autonomous vehicle, allowing the vehicle to perform these tasks. The software comprises three basic systems: perception, planning, and control.[91]

#### *a. Perception*

Autonomous vehicles use "perception systems" to interpret raw information from onboard sensors. Examples of this technology are object detection and object recognition. Object detection, the process of *finding* instances of objects in images, facilitates and complements object recognition, the computer vision technique for *identifying* objects in images or videos (see Figure 7).[92] Object recognition is the goal of "machine learning,"

90 Source: Charles McLellan, "What Is V2X Communication? Creating Connectivity for the Autonomous Car Era," ZDNet, November 4, 2019, https://www.zdnet.com/article/what-is-v2x-communication-creating-connectivity-for-the-autonomous-car-era/.

91 Huang, "How the Autonomous Car Works."

92 "Object Recognition," MathWorks, accessed December 7, 2019, https://www.mathworks.com/solutions/deep-learning/object-recognition.html.

also known as "deep learning" algorithms. These high-dimensional algorithms are what allow machines to learn more like humans.[93]

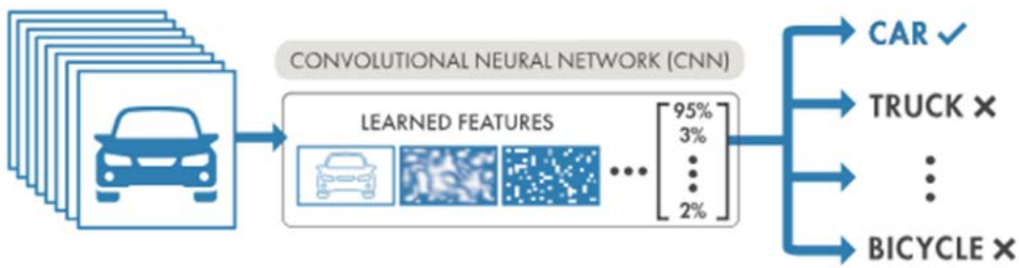



Figure 7. Machine Learning Example[94]

### *b. Planning*

Autonomous vehicles achieve higher-order goals, e.g., follow traffic laws, avoid pedestrians, and make decisions, thanks to their planning system. One example of a novel planning algorithm framework is the hard, real-time rapidly-exploring random tree (RRT). Its algorithms are used to create safe and efficient plans when subject to time constraints. RRT algorithms are designed to search high-dimensional spaces that have differential constraints arising from nonholonomy and dynamics as well as algebraic constraints, such as obstacles (see Figure 8).[95]

---

[93] MathWorks.

[94] Source: MathWorks, "Object Recognition."

[95] Steven M. LaValle and James J. Kuffner Jr., "Rapidly-Exploring Random Trees: Progress and Prospects," in *Algorithmic and Computational Robotics: New Directions*, 293–308 (Boca Raton, FL: CRC Press, 2001), 4.

```
BUILD_RRT(x_init)
  T.init(x_init);
  for k = 1 to K do
      x_rand ← RANDOM_STATE();
      EXTEND(T, x_rand);
  Return T
```

```
EXTEND(T, x)
  x_near ← NEAREST_NEIGHBOR(x, T);
  if NEW_STATE(x, x_near, x_new, u_new) then
      T.add_vertex(x_new);
      T.add_edge(x_near, x_new, u_new);
      if x_new = x then
          Return Reached;
      else
          Return Advanced;
  Return Trapped;
```

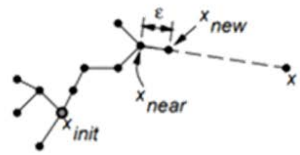



Figure 8. Rapidly-Exploring Random Tree[96]

#### *c. Control*

The operating or controlling system needs to navigate all other programs, tools, and platforms to optimize and manage the vehicle. The control system includes over 250 million lines of code on hardware in the vehicle alone.[97] There are 31 prominent operating codes being used by three or more companies producing autonomous vehicles.[98]

## C. DESCRIPTIVE RESULTS

### 1. Driver Survey

The driver survey was designed to establish what an average EMS response system in the state of Florida would look like regarding deployment, staffing, and training requirements for the driver.

Many U.S. communities use the fire service to deliver medical services. According to the International Association of Fire Chiefs, the three primary models include

- cross-trained/multi-role firefighters for EMS first response and ambulance transport,
- firefighters for EMS first response and civilians who are not cross-trained as firefighters for ambulance transport, and

[96] Source: LaValle and Kuffner, 4.

[97] Marks, “What Software Do Autonomous Vehicle Engineers Use?”

[98] Marks.

- firefighters for EMS first response and non–fire department organizations for ambulance transport.[99]

To establish a representative model of EMS response in Florida, Question 1 sought to determine whether the predominant response was a fire-based EMS model.[100]

**1. Does your agency operate a fire-based EMS model?**

| | Responses | Percent |
|---|---|---|
| Yes: | 2 | 100% |
| No: | 0 | 0% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

Figure 9. Question 1 Results

Both SME agencies identified as “fire-based.” The fire service delivers medical services to 97 percent of the 220 most populated communities in the United States.[101] Additionally, the fire service provides ALS response and care in 90 percent of the 30 most populated counties in the United States.[102] Florida is the third most populated state behind California and Texas, making the fire-based response a solid basis for comparative models.[103]

Since the research questions looked specifically to impact EMS, the model targets ambulances for autonomous vehicle augmentation. Question 2 polled the SME agencies to determine whether they are responsible for ambulances in their system.

---

[99] International Association of Fire Chiefs, “Position Statement: Fire-Based Emergency Medical Services” (Washington, DC: International Association of Fire Chiefs, May 7, 2009), https://www.iafc.org/about-iafc/positions/position/iafc-position-fire-based-emergency-medical-services.

[100] International Association of Fire Chiefs.

[101] International Association of Fire Chiefs.

[102] International Association of Fire Chiefs.

[103] Jim Saunders, “Florida’s Population Climbs, Now Third Most-Populous State,” *Northwest Florida Daily News*, February 18, 2019, https://www.nwfdailynews.com/news/20181219/floridas-population-climbs-now-third-most-populous-state.

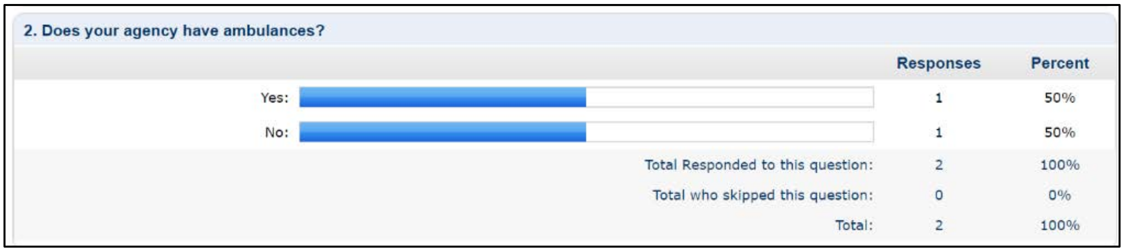



Figure 10. Question 2 Results

The poll confirmed that not all metro departments hold a certificate of public convenience and necessity for transport. Having SMEs from both transport and non-transport agencies increases the representative nature of questions pertaining to drivers. For this thesis, the "As Is" model presumes a transport-capable agency, and the "To Be" model evaluates an autonomous ambulance.

To determine the staffing level in the "As Is" model, Question 3 asked about minimum staffing on ambulances.


Figure 11. Question 3 Results

Both SME agencies identified two-person staffing as the minimum for their system, which aligns with Florida's statutory requirements and indicates an industry standard.

Not all fire-based agencies require all employees to be fire-certified. Some EMS systems operate under the auspices of the fire department but hire single-role employees for ambulances and quick-response vehicles.

**4. Is the driver of the ambulance required to be fire certified?**

| | Responses | Percent |
|---|---|---|
| Yes: | 2 | 100% |
| No: | 0 | 0% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

Figure 12. Question 4 Results

Question 4 confirmed that both SME agencies use multi-role, i.e., EMS and fire-certified, crews. Although the consistent responses identify a potential industry smart practice, fire training is excluded from the KVA evaluation as it does not pertain to medical or driving subprocesses.

Some agencies use the driver position as the first promoted position in their department. In these cases, the minimum requirements are usually higher as there are leadership and skill components expected for the position.

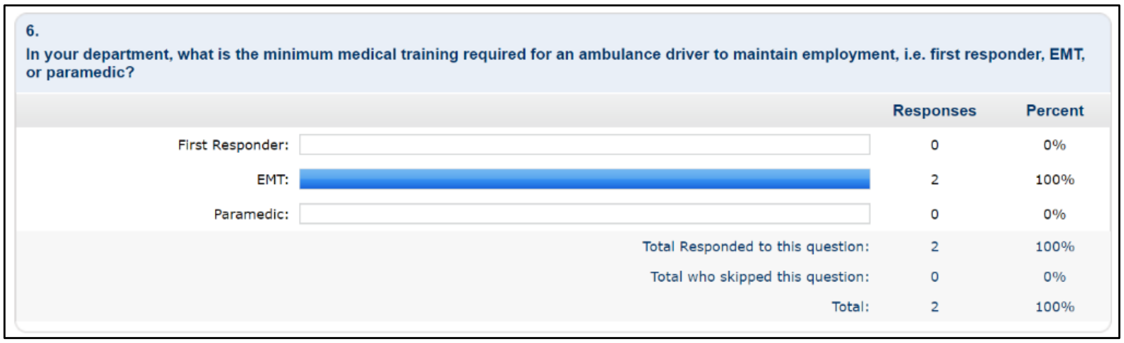
**5. Is the ambulance driver a promoted or entry level position in your department?**

| | Responses | Percent |
|---|---|---|
| Promoted: | 1 | 50% |
| Entry Level: | 1 | 50% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

Figure 13. Question 5 Results

One agency promotes drivers, and one agency allows entry-level drivers. Having SMEs in both categories increases representation in responses pertaining to drivers.

Some agencies require all employees to hold paramedic certifications. Question 6 sought to determine whether EMTs are viable in our conservative model.



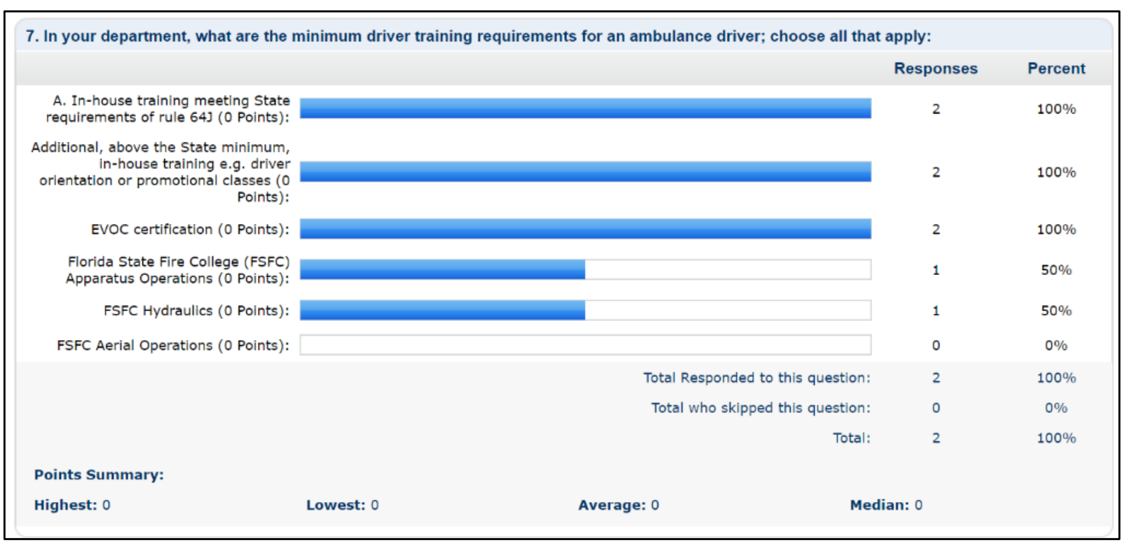
6.
In your department, what is the minimum medical training required for an ambulance driver to maintain employment, i.e. first responder, EMT, or paramedic?

| | Responses | Percent |
|---|---|---|
| First Responder: | 0 | 0% |
| EMT: | 2 | 100% |
| Paramedic: | 0 | 0% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

Figure 14. Question 6 Results

Question 6 confirmed that the minimum medical training for the ambulance driver is EMT, which aligns with state of Florida statutory requirements and indicates a minimum industry standard.

Question 7 was aimed at determining the minimum level of driver's training provided for ambulance drivers. SME agencies could pick more than one answer for the level of training required and what the training consisted of.



7. In your department, what are the minimum driver training requirements for an ambulance driver; choose all that apply:

| | Responses | Percent |
|---|---|---|
| A. In-house training meeting State requirements of rule 64J (0 Points): | 2 | 100% |
| Additional, above the State minimum, in-house training e.g. driver orientation or promotional classes (0 Points): | 2 | 100% |
| EVOC certification (0 Points): | 2 | 100% |
| Florida State Fire College (FSFC) Apparatus Operations (0 Points): | 1 | 50% |
| FSFC Hydraulics (0 Points): | 1 | 50% |
| FSFC Aerial Operations (0 Points): | 0 | 0% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

**Points Summary:**

**Highest:** 0 **Lowest:** 0 **Average:** 0 **Median:** 0

Figure 15. Question 7 Results

The results showed that, predominantly, drivers are required to have a 16-hour EVOC course as well as in-house training that meets the 16-hour requirement. Additionally, one of the SME agencies requires Florida State Fire College classes beyond this, which is consistent with agencies that use the “promoted” driver model.

To further clarify driver training, Question 8 was used to determine the number of in-house training hours, above the state minimum, that departments require from their drivers.

**8.**
**If you answered yes to question 7, “additional, above the State minimum, in-house training”, how many hours are required? If you previously answered in the negative, please enter zero.**

| | Responses | Percent |
|---|---|---|
| Responses: | 2 | 100% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

Figure 16. Question 8 Results

One SME agency indicated it requires eight to 16 hours of additional training.

Finally, to assist in determining ROI, Question 9 sought to establish an average starting pay for the ambulance driver.

**9.**
**What is the starting pay for an ambulance driver in your department?**

| | Responses | Percent |
|---|---|---|
| Responses: | 2 | 100% |
| Total Responded to this question: | 2 | 100% |
| Total who skipped this question: | 0 | 0% |
| Total: | 2 | 100% |

Figure 17. Question 9 Results

The high and low examples from the two SME agencies were used to populate hourly wages for drivers.

### 2. Interpretation

The driver survey suggests that a representative metro EMS agency in Florida is a fire-based agency employing multi-role responders. The driver would be medically trained to the EMT level. The driver would require an average of 24 additional in-house hours of training above those required for the EVOC. The mean starting pay for the driver would be $47,305.15. The EMS agency could be a first response agency that does not transport but calls for outside ambulances or a transport-capable agency with its own ambulances. Finally, the driver could be an entry-level or promoted position.

The results from the survey were used to populate the KVA calculation. Because this research was not designed as a staffing study, the only gaps between the “As Is” model and the “To Be” model were the addition of vehicle automation and the configuration needed to obtain the two-paramedic optimization.

The “As Is” and “To Be” models were populated with the following assumptions. First, the number of employees performing the medical subprocesses for an unstable patient in a fire-based system are calculated at a maximum of five and minimum of two. This proposes a standard response of one ambulance staffed with two multi-role responders and an all-purpose unit (APU), such as a fire truck, staffed with three multi-role responders, meeting NFPA 1710 recommendations. Second, for subprocesses that involve driving the vehicle, i.e., navigating and piloting, two responders are counted, and there is one driver per unit.

## D. EXPERIMENTAL RESULTS

### 1. Knowledge Value Added Calculation

This research used a KVA calculation to determine the value-add of the EMT’s medical and driving knowledge. This methodology was chosen for its ability to quantify intangibles like knowledge. KVA is the logical progression of more general theories of business based on computational complexity and thermodynamics. KVA uses the common units provided by computational complexity and the language of thermodynamics to provide a like comparison of processes.

KVA theory was created by Dr. Tom Housel from the Naval Postgraduate School and Dr. Valery Kanevsky from Agilent Labs. KVA assumes that the activity of industries, technology, and humans may be reduced to inputs and outputs.[104] Smart et al. contend,

> Units of change, or complexity, are universal units and can be described in a common language based on the knowledge required to reproduce the changes. KVA further assumes that firms are open systems that rely on performance feedback to self-organize in reaching their goals. The implications of this assumption are that if management is provided concurrent feedback on their utilization of knowledge assets, they will self-organize to produce the best outcomes for the firm.[105]

### 2. KVA Assumptions

Conditional complexity is the shortest description of a process, e.g., *C* (*x*/*y*). Once described, this description may be used to measure the value added by the process through entropy increment comparison.[106] This concept may be used to quantify the value added by a process and the efficiency of automation embedded within it by calculating the input to its process output. This is possible because of a parallelism between business processes and computing.[107] Smart et al. conceived the following:

> If . . . process (P), can be formally represented as a set of instructions in formal language: (1) there is a universal computer U equipped with program p; (2) there is a one-to-one map from {a} to {x}, where {a} is the set of all possible inputs to process P, and {x} is the set of all possible inputs to computer U; and (3) there is a one-to-one map from {b} to {y}, where {b} is the set of all possible outputs from process P, and {y} is the set of all possible outputs from U acting on {x} by virtue of p, such that *U (p, x) = y*, if and only if *P (a) = b*.[108]

As described by thermodynamics, the change in structure may be calculated by the change in entropy. In other words, when the input (a) is processed into output (b) by process

---

[104] P. Andi Smart et al., "An Approach for Identifying Value in Business Processes," *Journal of Knowledge Management* 7, no. 4 (2003): 53, https://doi.org/10.1108/13673270310492949.

[105] Smart et al., 53.

[106] Ming Li and Paul Vitanyi, *An Introduction to Kolmogorov Complexity and Its Applications*, 3rd ed. (New York: Springer, 2008), 1.

[107] Li and Vitanyi.

[108] Smart et al., "An Approach for Identifying Value in Business Processes."

(P), then *b = P(a)*. It should be noted that a change in entropy when input (a) is transformed into output (b) does not depend on process (P), but only on (a) and (b).[109] Therefore, any process that transforms (a) into (b) creates an identical change in entropy. Then, it follows that process (P) is such that output (b) is equal to input (a); e.g., if $b = P(a) = a$, then no value is added by process (P).[110] Ergo, "no changes = no value added."[111] While fundamental, this relationship does not equate to a practical methodology for calculating the value added by process (P). How then can we evaluate the process to achieve optimization? One way to quantify the value added by process (P) is through the difference of the entropies, i.e., $E = E(b) – E(a)$, or the amount of work required to transform input (a) to output (b).[112] In this scenario, the difference in entropies, (E) is proportional to the amount of thermodynamic work required for the change.[113] Ergo, the amount of value added by process (P) may be proportion to the corresponding change in entropy, or the "entropy increment."[114] To determine the value added by process (P), one may use the established relationship between the process entropy increment and conditional complexity. It follows that the value added by process (P) when (a) is transformed into (b) is proportional to $C(x/y)$, where $x$ and $y$ correspond with (a) and (b), as defined previously. The value added by (P) varies with the level of detail used to describe (P).

Central to KVA is the concept of value added through knowledge. When presented with intangibles like those found in manual multi-variable processes, it may be necessary to evaluate the knowledge required, not the exact steps to achieve the process flow. Estimating the length of time it takes the average person to learn how to produce the outputs of a process, or "learning time" (LT), is one example of how the amount of knowledge

---

[109] Smart et al., 53.

[110] Smart et al., 53.

[111] Smart et al., 53.

[112] Smart et al., 53.

[113] Thomas J. Housel et al., "Measuring the Return on Knowledge Embedded in Information Technology," in *Proceedings of the 22nd International Conference on Information Systems* (Atlanta: Association for Information Systems, 2001), 101, https://pdfs.semanticscholar.org/ee4d/64c897abae1e4f62ebfc4f4d880cc2847568.pdf.

[114] Housel et al., 101.

contained within a process may be quantified.[115] Within the context of KVA, LT allows an estimate of the amount of knowledge required for the processes and their supporting technology. Smart et al. contend that this assumption means “the average time it takes to learn a process with predetermined outputs is proportionate to the amount of knowledge acquired and that this is in turn proportionate to the change produced by the process.”[116] As knowledge in the KVA context is proportionate to LT and complexity, so must that knowledge be proportional to the value added. Therefore, a monetized ROK can be calculated, given that

ROK = (TLTU * (Process Price per Year/Summed TLTU))/Process Cost per Year

### 3. KVA Examples

As a specific example of how KVA is applicable to EMS, the following examines a medical response as a sub-system within the EMS, where

*C* (*x*/*y*) = Medical Response (Medical 9-1-1 Call/Patient Treatment or Transfer)

Each system may consist of one or more subsystems, and each subsystem may be broken down into strictly defined subprocesses. For example, an EMS system might have a subsystem that was responsible for a medical response that carried out the subprocesses shown in Table 3.

[115] International Engineering Consortium, “Knowledge Value-Added (KVA) Methodology” (Chicago: International Engineering Consortium, 2019), 5, http://cmapspublic3.ihmc.us/rid=1G9L62WTW-NJ5G5D-C84/KVAmethodology.pdf.

[116] Smart et al., “An Approach for Identifying Value in Business Processes,” 54.

Table 3. Subprocess Example

| | Subprocess Name | Subprocess Description |
|---|---|---|
| **P1** | Map Location | Using a city grid system, the driver pinpoints the location of the incident by establishing the geographical quadrant; locating the avenue, place, road, or lane (APRL) or street, terrace, or drive (STD), depending on the compass direction of travel; zooming to the appropriate hundred block; determining the correct side of the road based on even or odd address numbers; and finally pinpointing the exact address. |
| **P2** | Determine Route | Using a back-planning methodology, the driver creates the best route considering speed, efficiency, and safety. |
| **P3** | Ready Vehicle | The driver conducts a 360-degree inspection of the vehicle to ensure all compartments are secure and no foreign object debris is blocking the vehicle. |
| **P4** | Navigate | The driver travels over the terrain with care while avoiding difficulty. |
| **P5** | Pilot Vehicle | The driver controls the vehicle, adjusting to the mission, environment, time, and terrain and employing the defensive driving techniques of observation, orientation, decision, and action looped in a continuous cycle. |
| **P6** | Dev. Diff. Diagnosis | Patient assessment of a medical or trauma patient. |
| **P7** | Stabilizing Treatment | Application of BLS or ALS skills as indicated by local protocol prior to transport (not to exceed 10 minutes in a trauma patient). |
| **P5** | Pilot Vehicle | See above. |
| **P9** | Transport Continuing Treatment | Application of BLS or ALS skills as indicated by local protocol during transport. |
| **P10** | Patient Transfer | Patient care report given to provider of equal or higher certification. |
| **P11** | Documentation | An electronic patient care report is generated. |

The actions associated with each subprocess can then be further distilled into individual components required to make that subprocess function. The components involved in subprocess P1, Map Location, for example, are shown in Table 4.

Table 4. Subprocess Component Example

| **P1** | **Map Location** |
|---|---|
| 1 | Establish the geographical quadrant within the jurisdiction |
| 2 | Locate the APRL or STD |
| 3 | Zoom to appropriate hundred block |
| 4 | Determine the appropriate side of the road based on even or odd address numbers |
| 5 | Pinpoint exact location |

Accurately determining the KVA of a process entails defining certain required variables, including process price, the number of employees performing a subprocess, learning time, average hourly cost per subprocess, subprocess times performed in a year, and the average time to complete the subprocess.

First, we must calculate the process price. This is how much someone is willing to pay per process. An example might be renting a movie. If the going price to stream a movie from a service is $1.99, the process price would be $1.99. If the price varies, e.g., because there are additional costs for newer movies, high-definition movies, or director’s cuts, then we may have to look at the overall revenue divided by the number of processes, i.e., movies, to establish a baseline price per process.

To determine whether this pricing is solvent, we must examine the ROI. In business, one might use profit compared to investment, or ROI = Profit/Investment. In not-for-profit organizations, this is complicated as profit is not present or correlative to investment and, by business standards, operates at a break-even or loss. In these situations, or when specifics are unknown, a mark-up of 1.5 percent can be used above the yearly sum of subprocess costs to account for overhead as a market comparison of revenue. However, in the case of the emergency services, the situation is further complicated by “emergency units” being an “off-the-shelf” resource. In other words, fire trucks and ambulances must be available in a sufficient quantity around the clock, regardless of whether there is a steady demand. This excess creates the reserve capacity required for a healthy EMS system. There are many ways to calculate the cost of running EMS calls, each with its own bias. Variations include the total operating cost, cost assigned per incident, marginal cost per incident plus labor, and marginal cost per incident with no labor.

The following example uses the total operating cost methodology. Lakeland, Florida, one of the SME agencies, had a 2019 fire department budget of $20,606,270. Assuming a low-volume call load of 20,000 calls per year, the cost of one EMS response would be $1,030.32. Returning to the video rental analogy, this would equate to purchasing a yearly subscription for $20,606,270, allowing access to watch unlimited movies. However, if we watched only 20,000 in a year, the price per movie would be $1,030.32. Therefore, $1,030.32 may serve as the revenue surrogate per response. Since modeling is at the process and subprocess levels and quantifies the value-add of personnel, we must isolate the price of just the personnel and automated equivalent. Municipal agencies spend upward of 63 percent of their budgets for total rewards benefits per year for employees, with high-risk departments gravitating to the higher end.[117] For this research, 63 percent of the operating budget is used for the price of personnel and the automated equivalent. Ergo, the isolated price of personnel per process is $649.10.

Second, we must determine the number of employees performing the subprocess. Individual responders may be assigned to multiple processes. Additionally, several responders may be assigned to each subprocess. This multiplying factor may increase the summed elapsed time and complexity seen in analyzing EMS system performance. This demonstrates why detailed analysis is necessary. Analysis may explain factors such as the crew’s experience level that would be difficult to capture via an algorithm.

Third, we evaluate LT. To parallel state requirements, LT is measured in hours. It should be noted that KVA only measures knowledge in use, not in inventory. In other words, if someone has a PhD in Celtic drama studies, but they only use the barista portion of their training, then the doctorate is irrelevant in calculating the training time for making expensive coffee. This differs somewhat for the medical profession, where one gets paid not for what they do but what they know—because medical treatment is a “wicked” problem. A wicked problem is a problem that is difficult or impossible to solve because of

[117] Cindy Nevitt, “Cost of Government: Most Tax Dollars Go toward Salaries & Healthcare,” *Press of Atlantic City*, March 24, 2015, https://www.pressofatlanticcity.com/news/breaking/cost-of-government-most-tax-dollars-go-toward-salaries-healthcare/article_23f00e24-cef0-11e4-bfa7-7b06dcd8f32b.html; City of Lakeland, *Budget Overview* (Lakeland, FL: City of Lakeland, 2019), B-14, https://www.lakelandgov.net/media/8683/section-b-budget-overview.pdf.

its complex and interconnected nature.[118] The pre-hospital practitioner must evaluate and develop a differential diagnosis and treat patients experiencing multiple, complex, paradoxical problems. Therefore, for this research, LT for medical-related subprocesses is set at 3,080 hours for two-paramedic optimization and 4,400 hours for a full two-unit response consisting of two paramedics and three EMTs. LT for driving-related subprocesses is 40 hours. This time was derived from a 16-hour EVOC course with an additional 24 hours of training provided on the department level, as identified in the driver survey.

Fourth, we determine the average labor cost per subprocess. Question 9 of the driver survey showed the greatest disparity between SME organizations with a range of starting pay from $33,321.60 for an entry level EMT/driver to $50,115.33 for a promoted EMT/ driver to $58,478.53 for a promoted paramedic driver. The mean starting pay would be $47,305.15. For greater accuracy in the KVA calculation, the hourly pay is calculated for a 52-hour work week, with an EMT paid $12.32 per hour in the lower range and paramedics $21.62 per hour in the higher range. This hourly rate does not account for Fair Labor Standards Act overtime, fringe benefits during employment, or retirement benefits in perpetuity.

Fifth, we quantify EMS calls, the times performed in a year. For this research, 20,000 is used as a low-volume example and 40,000 as a high-volume example.

Finally, we determine the work time or average time to complete (ATC) in hours for each subprocess. For this study, the ATC for subprocesses was determined using national benchmarks.

[118] "Wicked Problems," Austin Center for Design, accessed December 7, 2019, https://www.wickedproblems.com/1_wicked_problems.php.

Table 5. Average Time to Complete Subprocesses

| | |
|---|---|
| Map Location | Mapping the location, determining the route, and readying the vehicle remain a constant, set at 33.33 seconds each, to fall within the one-minute "turnout" time indicated in NFPA 1710.[119] |
| Determine Route | |
| Ready Vehicle | |
| Navigate | Navigating remains a constant, set at four minutes, to fall within the allowable "travel" time outlined in NFPA 1710.[120] |
| Pilot Vehicle | Piloting the vehicle remains a constant, set at four minutes, to fall within the allowable "travel" time outlined in NFPA 1710.[121] |
| Dev. Diff. Diagnosis | Developing a differential diagnosis and stabilizing treatment remains a constant, set at five minutes each, to fall within the "platinum" 10 minutes of the golden hour outlined in pre-hospital trauma life support.[122] |
| Stabilizing Treatment | |
| Pilot Vehicle | Ten minutes are used as a short transport example and 20 minutes as a long transport example. |
| Continuing Treatment | Continuing treatment is set at the same time as transport. |
| Patient Transfer | Unloading the patient, checking in the patient, giving a report, and placing the vehicle back in service remains a constant set at 15 minutes. |
| Document | Completing the patient care report remains a constant set at 15 minutes. |

Now that the constants and variables have been determined, we may calculate a specific example of ROK as it relates to EMS.

---

[119] National Fire Protection Association, NFPA 1710.

[120] National Fire Protection Association.

[121] National Fire Protection Association.

[122] Kara Rogers, "Battlefield Medicine: The Golden Hour and the Platinum Ten," *Encyclopedia Britannica Blog*, June 23, 2011, http://blogs.britannica.com/2011/06/battlefield-medicine-golden-hour-platinum-ten/.

THIS PAGE INTENTIONALLY LEFT BLANK

# III. FINDINGS

The “As Is” model in Appendix A presumes a multi-tiered dispatch of an ambulance and APU to a “chest pain–delta” patient as described in the introduction. To meet the two-paramedic optimization, the model presumes that both EMS units must escort the patient to the hospital—one unit for transport and the other for continuing care assistance and crew retrieval. The model was run showing a low-volume response (20,000), a high-volume response (40,000), short transport times (10 minutes), and long transport times (20 minutes), as these are independent variables even between metro departments.

## A. “AS IS”

The “As Is” model showed ROK across all medical-based subprocesses. However, ROK decreased as the crew configuration changed for transport. The “As Is” model also displayed an inverse relationship between ROK and subprocess time. This means that ROK drops when responders are detailed to non-medical tasks and worsens the longer a subprocess takes.

ROK was used to measure system productivity. Models showed ROKs between 666 and 2,576 for all medical subprocesses. This demonstrates the value-add of EMTs and paramedics vis-à-vis their medical knowledge. ROK was higher when the maximum number of responders were focused solely on patient care as in the differential diagnosis and stabilizing treatment subprocesses. When ROK is graphed for the subprocesses, there was a decrease in ROK as the crew configuration changed to allow for transport. This is because the drivers are not released and are no longer available for patient care, negating their medical knowledge.

Additionally, the “As Is” model also showed a paradoxical relationship between transport time and ROK. Because continuing treatment is the only medical subprocess effected by time, between “As Is” models, the author sees an inversion in the continuing treatment subprocess ROK as the transport time increases from 10 to 20 minutes (see Figure 18).

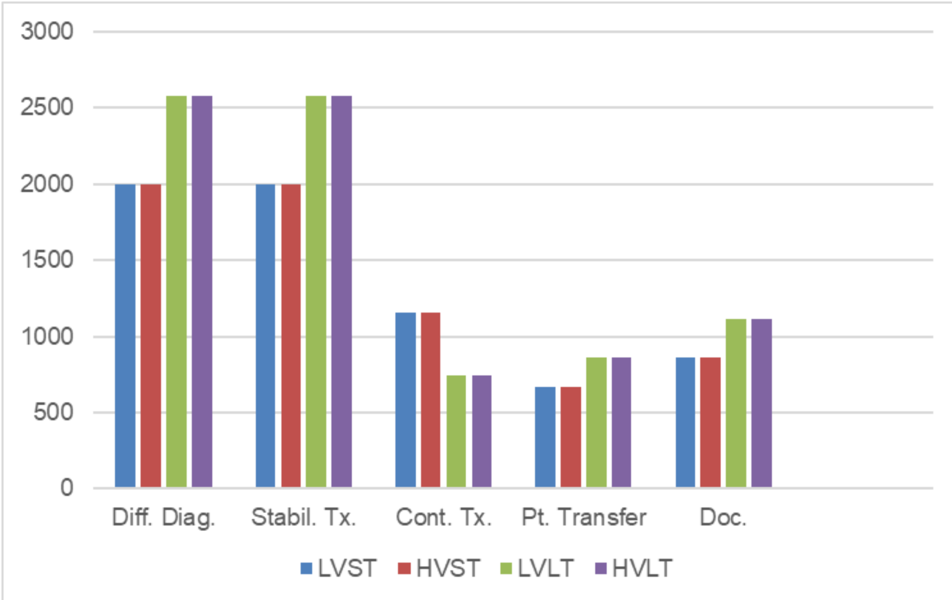


Figure 18. “As Is” Medical ROK Graph

For most driver-based subprocesses, the “As Is” model showed lower ROKs and an inverse relationship between ROK and transport time.

Models showed minimal ROK for driver subprocesses, which indicates that driving is a poor use of the employees’ overall knowledge. ROKs for driver subprocesses were as low as 38 percent when piloting the vehicle to the hospital during long transport times. This example is tantamount to a medical doctor with eight years of training checking vital signs for all patients. Over the course of the day, the doctor could see extra patients if this task was left to a more appropriate provider with one or two years of training. Again, subprocess ROKs were higher when the maximum number of responders focused solely on one task. This is most notably seen in the ready vehicle subprocess, which has ROKs as high as 39,039. Notably, even though ROK may be very high, it is productivity and efficiency, not ROI, being measured. ROK is high because the crew can complete the task quickly; however, this does not translate into more outputs because, in EMS, call volume does not depend on process time.

Once again, when ROK for subprocesses is graphed, there is a significant decrease in ROK as the crew configuration changes to allow for transport. This finding reinforces the “As Is” paradoxical relationship between transport time and ROK. Because piloting the vehicle to the hospital is the only driver subprocess affected by time, between the "As Is" models, the author sees an inversion in ROK in this subprocess. In fact, the piloting vehicle to hospital subprocess is the only time that short-transport models overtake long-transport models in ROK. Time, not volume, was the biggest variable in ROK in the "As Is" model.

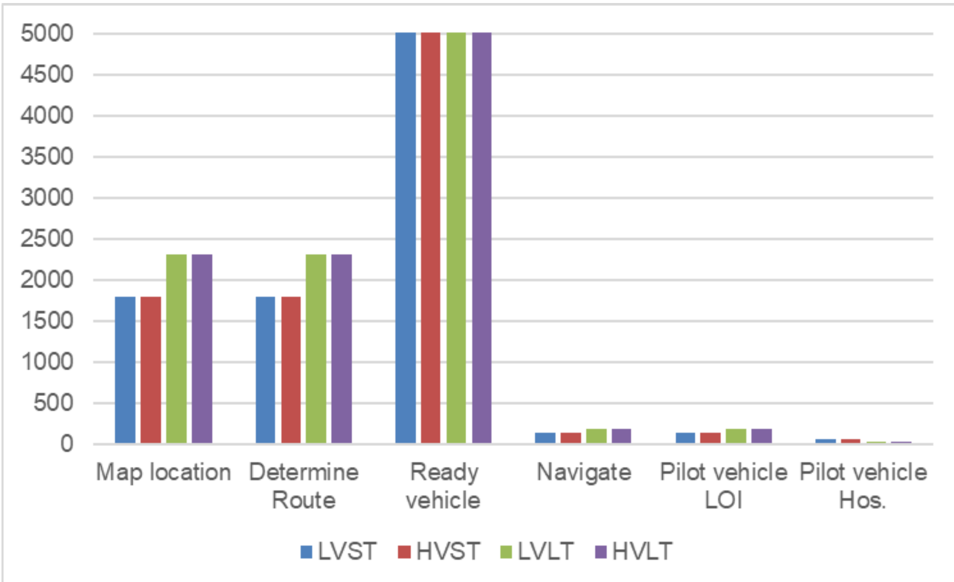



Figure 19. "As Is" Driver ROK Graph

## B. "TO BE"

There is a learning curve for automation known as technological readiness. Readiness levels range from "basic principles observed and reported" to the "actual system proven through successful system and/or mission operations" (see Figure 20).[123]

[123] John C. Mankins, "Technology Readiness Assessments: A Retrospective," *Acta Astronautica* 65, no. 9 (2009): 1216–23, https://doi.org/10.1016/j.actaastro.2009.03.058.

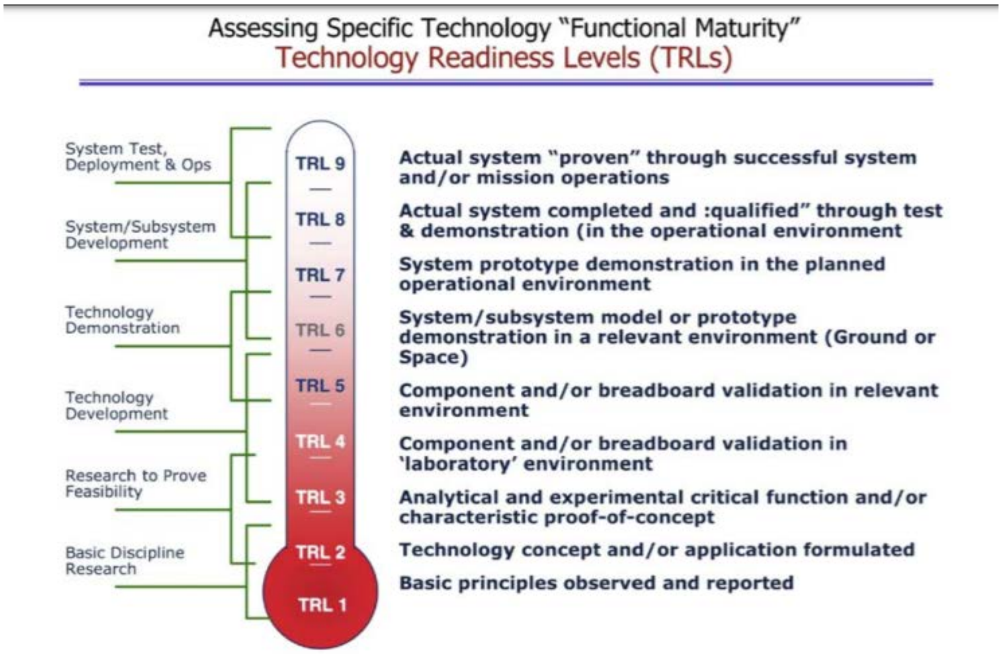



Figure 20. Technology Readiness Levels[124]

The "To Be" model in Appendix B presumes a maturation to technology readiness level 9 and level 5 autonomy, meaning "an Automated Driving System (ADS) on the vehicle can do all the driving in all circumstances. The human occupants are just passengers and need never be involved in driving."[125] Further, modeling was based on a multi-tiered dispatch of an ambulance and APU to a critical patient. To meet the two-paramedic optimization, the model presumed that the autonomous ambulance was staffed with two paramedics and that during transport, only one EMS unit remained committed. The APU could go back into service even on critical patients. The model was run showing low-volume response, high-volume response, short transport times (10 minutes), and long transport times (20 minutes), as these are independent variables even between metro departments.

The "To Be" model showed superior ROK across all variations of driver subprocesses and most medical subprocesses, except documentation.

124 Source: Mankins, "Technology Readiness Assessments."

125 National Highway Traffic Safety Administration, "Automated Vehicles for Safety."

ROK increased in the differential diagnosis, stabilizing treatment, continuing treatment, and patient transfer subprocesses vis-à-vis the “As Is” model. This change was expected based on the substitution of the ambulance EMT for a second ambulance paramedic. Thus, in the early medical subprocesses, there is more knowledge to bring to bear on the problem. During the latter subprocess, the two-paramedic optimization is achieved with the ambulance crew alone. This removes one EMT’s knowledge from the “continuing treatment” subprocess and two EMTs’ knowledge from the patient transfer subprocess. However, the overall ROK increases marginally, even with less resources, through system optimization.

System optimization was not passed on to the documentation subprocess in the “To Be” model. The subprocess required two paramedics in the “As Is” model and two paramedics in the “To Be” model. Therefore, ROK decreased marginally from a low of 864 in the “As Is” model to a low of 809 in the “To Be” model (see Figure 21).

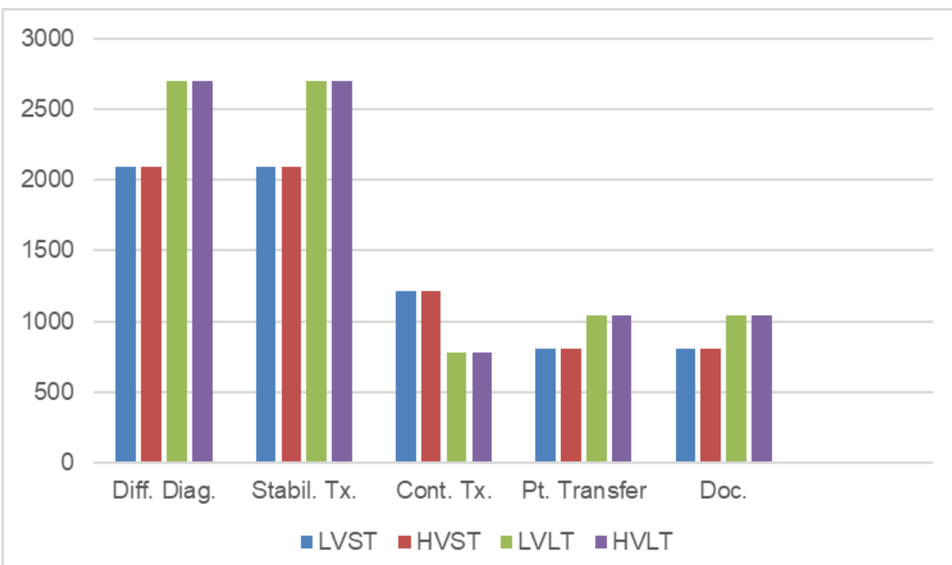



Figure 21. “To Be” Medical ROK Graph

The “To Be” model showed exponential increases in ROK for all driver subprocesses as compared to the “As Is” model. Moreover, for driver subprocesses, increasing transport times and increasing call volume both increased ROK in the “To Be” model. This effect was most apparent in the pilot vehicle to hospital subprocess, which had ROKs of 3,243 in the low-volume, short-transport "To Be" model and 8,367 in the high-volume, long-transport "To Be" model.

The increase in ROK for driver subprocesses was consistent with the addition of automation and the restructuring of the deployment model necessary to achieve the two-paramedic optimization.

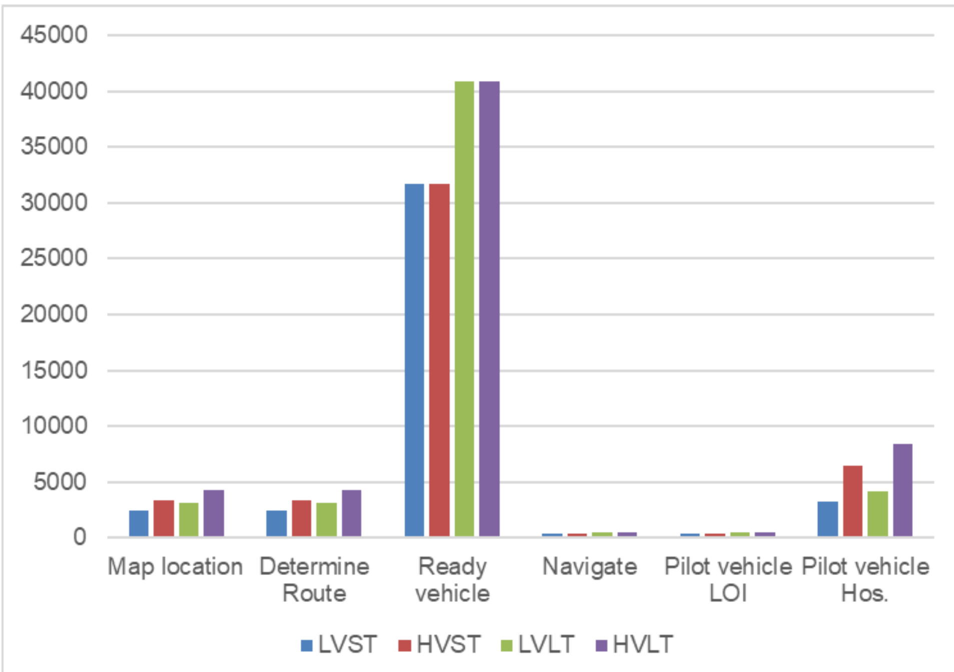
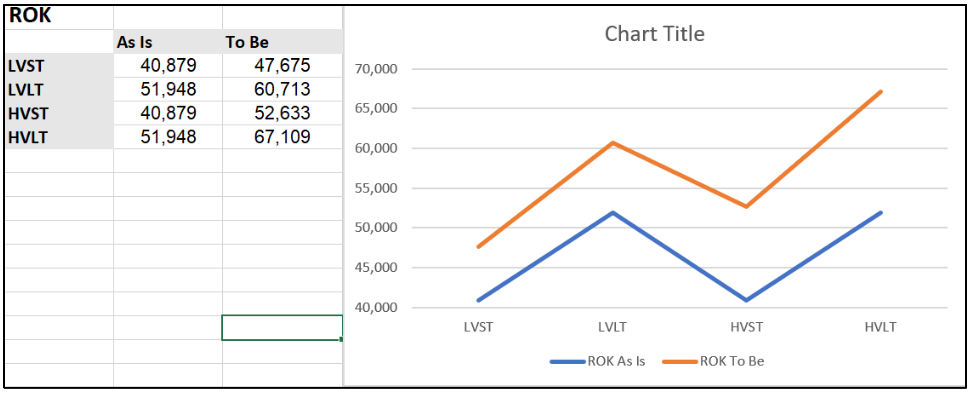



Figure 22. "To Be" Driver ROK Graph

Finally, when graphed, the "To Be" model showed greater resiliency to the transport time paradox and overall ROK increases with increased call volume. This means the "To Be" model increased efficiency the more it was used (see Figure 23).



| ROK | As Is | To Be |
|---|---|---|
| LVST | 40,879 | 47,675 |
| LVLT | 51,948 | 60,713 |
| HVST | 40,879 | 52,633 |
| HVLT | 51,948 | 67,109 |



Figure 23. ROK Comparison of “As Is” and “To Be” Models

THIS PAGE INTENTIONALLY LEFT BLANK

# IV. CONCLUSION

The research showed a quantifiable value-add in the "To Be" model from the autonomous technology application compared to the current "As Is" model. The author identified capacity and productivity as the litmus test. The research concluded that the "To Be" model increased both capacity and productivity.

## A. CAPACITY

The measure of performance for capacity was the number of EMS units used during the process phase. If the process could be optimized so that less units were needed per call, then overall system capacity would increase. The "To Be" model proved that the introduction of autonomous vehicles into EMS response would increase capacity.

Table 6. Capacity Comparison of "As Is" and "To Be" Models

| | LVST | | LVLT | | HVST | | HVLT | |
|---|---|---|---|---|---|---|---|---|
| | As Is | To Be | As Is | To Be | As Is | To Be | As Is | To Be |
| # of Responders to meet 2 paramedic optimization | 5 | 2 | 5 | 2 | 5 | 2 | 5 | 2 |
| TLTU | 492,000,000 | 526,000,000 | 492,000,000 | 526,000,000 | 984,000,000 | 1,052,000,000 | 984,000,000 | 1,052,000,000 |
| ROK | 40,879 | 47,675 | 51,948 | 60,713 | 40,879 | 52,633 | 51,948 | 67,109 |
| # Units Assigned | 2 | 1.63 | 2 | 1.63 | 2 | 1.63 | 2 | 1.63 |
| Cost per Year | $1,231,816.13 | $927,275.40 | $1,499,149.47 | $1,071,408.73 | $2,463,632.27 | $1,847,550.80 | $2,998,288.93 | $2,135,817.47 |
| ROI | 39,779 | 46,575 | 50,848 | 59,613 | 39,779 | 51,533 | 50,848 | 66,009 |

Staffing changes and automation allowed one EMS unit to meet the two-paramedic optimization during transport. This effect increased EMS unit capacity system-wide. In fact, unit utilization rates in the "To Be" model reached 1.63 units vis-à-vis 2 units in the "As Is" model.

## B. PRODUCTIVITY

The measure of performance for productivity was ROK. If a greater ROK could be shown with the same number or fewer responders, then productivity could be shown to have increased. The "To Be" model proved that the introduction of autonomous vehicles into EMS response would increase ROK.

Factors effecting productivity were noted during the distillation of subprocesses into individual components in both the “As Is” and “To Be” models. In the “As Is” model, EMT drivers use their medical training only one-third of the response continuum. In the “To Be” model, the second responder can assist with prepping equipment and the donning of PPE during the response and before arriving on scene. Further, the second responder may assist in patient care after contact and during transport, unencumbered with getting to the hospital, maneuvering the vehicle, or negotiating traffic. This means the value-add of the medical skill set of the second crewmember, previously the driver, is deployable throughout the entire call continuum. Finally, after the call, the unit may be placed back into service more quickly as the EMT and paramedic may continue cleaning the patient compartment while enroute to the next call.

Table 7. Productivity Comparison of “As Is” and “To Be”

| | LVST | | LVLT | | HVST | | HVLT | |
|---|---|---|---|---|---|---|---|---|
| | As Is | To Be | As Is | To Be | As Is | To Be | As Is | To Be |
| # of Responders to meet 2 paramedic optimization | 5 | 2 | 5 | 2 | 5 | 2 | 5 | 2 |
| TLTU | 492,000,000 | 526,000,000 | 492,000,000 | 526,000,000 | 984,000,000 | 1,052,000,000 | 984,000,000 | 1,052,000,000 |
| ROK | 40,879 | 47,675 | 51,948 | 60,713 | 40,879 | 52,633 | 51,948 | 67,109 |
| # Units Assigned | 2 | 1.63 | 2 | 1.63 | 2 | 1.63 | 2 | 1.63 |
| Cost per Year | $1,231,816.13 | $927,275.40 | $1,499,149.47 | $1,071,408.73 | $2,463,632.27 | $1,847,550.80 | $2,998,288.93 | $2,135,817.47 |
| ROI | 39,779 | 46,575 | 50,848 | 59,613 | 39,779 | 51,533 | 50,848 | 66,009 |

Because of the off-the-shelf mentality used to populate LT, what ROK really measures in this research is productivity, redundancy, and resiliency. A model with greater ROK has more available knowledge on scene and more medical oversight, i.e., knowledge to draw from, and is not as dependent on each individual. The outcome is the mathematical equivalent of “two heads are better than one” and “many hands make light work.”

In addition, the “To Be” model shows greater resilience to cost, which here represents only wages per hour and automation cost as call volume and transport time increase.

| Cost per Year | | |
|---|---|---|
| | As Is | To Be |
| LVST | $ 1,231,816.13 | $ 927,275.40 |
| LVLT | $ 1,499,149.47 | $1,071,408.73 |
| HVST | $ 2,463,632.27 | $1,847,550.80 |
| HVLT | $ 2,998,288.93 | $2,135,817.47 |

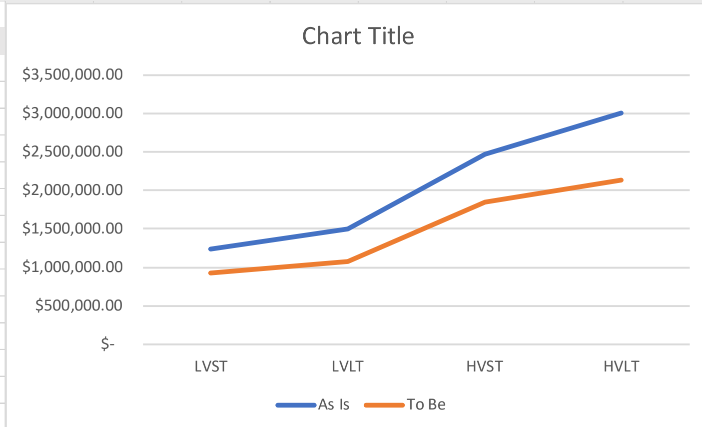



Figure 25. “As Is” versus “To Be” Cost Comparison

## C. LIMITATIONS

Excluded from the discussions in this study were the financial impact, nursing dispatch models, other workplace factors that might affect EMS recruitment and retention, higher-order consequences of automation, and additional applicability of KVA to the emergency services.

In the “To Be” model, the value-add by the EVOC driver was transferred and included in the cost of the vehicle; moreover, these “To Be” costs needed not include benefits in perpetuity like human responders. Further studies are recommended to ascertain whether automation would be cost prohibitive or financially beneficial, and over what timeline.

The modeling included in this research proposed that all calls were emergent “unstable” patients. This research did not consider emergency severity in modeling or evaluate changes in dispatch protocols to increase efficiency. Further research is recommended to determine whether “nursing dispatch” protocols would allow a single unit to be dispatched to non-emergent patients while still maintaining safety margins.

Additional options that might affect recruitment and retention, such as total rewards packages or Hertzberg hygiene factors, were not considered in this research. Further research into the ROI of additional methodologies is recommended for comparison.

Second- and third-order consequences of automation were not considered in this research. Thus, future studies ought to focus on objectively comparing the differences and similarities between human drivers and autonomous vehicles. There are tradeoffs to optimization through autonomy. Although the learning time for the subprocesses for which autonomy is designed has been transferred, some generalized knowledge is lost. Autonomous vehicles cannot be another pair of eyes looking for child abuse on emergency scenes. Autonomous vehicles will not report that their partner is suffering from post-traumatic stress disorder. Autonomous vehicles cannot go in the house to assist in lifting the 350-pound patient off the floor. However, it may be possible for the two models to calibrate and validate one another for optimization.

Finally, this research showed the value of KVA analysis. Using KVA analysis to identify ROK and ROI is a valuable deployment and acquisition tool. These metrics can assist leaders in making data-driven acquisition and optimization decisions. It is possible that KVA performance analysis would benefit the fire service in other areas. Although this was a relatively small-scale exploratory study, consensus among SME participants to populate the "As Is" model and the interdependence identified in the mathematical models will garner confidence in the general applicability of the KVA methodology.

## D. IMPACT

The KVA assessment showed increased efficiency in the "To Be" model and might indirectly assist with the problem of EMT and paramedic shortages through more efficient use of current resources. This is because autonomy is a "game changer" for EMS units that has the potential for widespread effects.

The "To Be" model decreases workloads for non-transport units by eliminating the need to "ride in" to meet the two-paramedic optimization. Further, transport units would always have two paramedics for patient care, even in non-critical patients. Workload is decreased between calls as well. Ambulance crews need not focus on driving when returning to zones, on return trips from transfers, during move-ups, or during system status deployment. The crew may relax in the "box" and destress or work on reports. A decrease in workload leads to better hygiene factors and, by proxy, recruitment and employee retention.

Not all the benefits focus on the crew. Future AI models of CAD could deploy ambulances based on probability models. This automated deployment has the potential to remove human error in staging and enroute times and may eliminate the need for individual stations for peak-time units.

THIS PAGE INTENTIONALLY LEFT BLANK

# V. RECOMMENDATIONS

Measuring EMS effectiveness based on KVA output provided the author with an analytical understanding of system capacity and productivity and will allow leaders to make informed hiring and procurement decisions. By using agency-specific data, administrators may judge the reserve capacity and productivity of their agencies.

Once autonomous technology reaches maturation, the “To Be” model is a viable way to optimize existing resources, thereby increasing system capacity, reducing individual workload for transport units, and reducing the total call time of non-transport units. According to the research, vehicle hardware and software technology already exist. Early adopters will have to invest in V2X infrastructure to increase safety margins.

Before implementation in a specific system, research should be conducted to verify that all data represent a region, so a reliable and valid KVA analysis for that system is performed. This will ensure previously established assumptions are valid.

The next steps in embedding autonomous vehicles into the EMS system include the following:

1. Maturation of autonomous technology to readiness level 9 and autonomy level 5
2. Identification of a trial agency
3. Installation of smart-city infrastructure
4. Incorporation of emergency medical dispatch software for call triage, if not present
5. Delivery of an autonomous vehicle with all required software
6. Training for responders on the software interface.
7. Ambulance staffing with two paramedics and one driver for safety during trial period

Although not a long-term solution, during the initial software implementation learning curve, three-responder staffing is recommended for safety purposes. Additionally, research into the best integration and deployment of autonomous vehicles within the system (e.g., dispatch to all calls, A-B severity calls only, or C-E severity calls only; stationing; or system status) is recommended.

To summarize, the results of this study suggest the “To Be” model, which includes autonomous vehicle adoption, is recommended to assist in system optimization by increasing both system capacity and productivity. The recommended trial agencies include those having difficulties meeting staffing needs, any agency taxing its reserve capacity and ability to expand, and any agency whose volume is creating a negative work environment. The combination of both cost savings and decreases in workloads should lead to greater EMS recruitment and retention, thereby helping to combat EMS staffing shortages.

# APPENDIX A. KVA APPLIED TO THE "AS IS" MODEL

Table 8. KVA "As Is" Low Volume Short Transport

| As Is Model: Driver | Volume(20000)Transport(10min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+ (#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 2 | 0 | 0% | 20000 | 0.0055 | $ 0.14 | $ - .0 | Turnout |
| **Determine Route** | 2 | | | 2 | 0 | 0% | 20000 | 0.0055 | $ 0.14 | $ - .0 | |
| **Ready Vehicle** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.0055 | $ 0.44 | $ - .0 | |
| **Navigate** | 2 | | | 2 | 0 | 0% | 20000 | 0.066666667 | $ 1.64 | $ - .0 | Travel |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 20000 | 0.066666667 | $ 1.64 | $ - .0 | |
| **Dev. Diff. Diagnosis** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 6.68 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 6.68 | $ - .0 | |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 20000 | 0.166666667 | $ 4.11 | $ - .0 | Transport |
| **Continuing Treatment** | | 1 | 2 | 3 | 0 | 0% | 20000 | 0.166666667 | $ 9.26 | $ - .0 | |
| **Patient Transfer** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.25 | $ 20.05 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 20000 | 0.25 | $ 10.81 | $ - .0 | Document |
| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
| **Map location** | 2 | 0 | 80 | 80 | 1,600,000 | $ 2,710.40 | $ 71,401.00 | $ 48,543.53 | $ 2,710.40 | 1791% | 1691% |
| **Determine Route** | 2 | 0 | 80 | 80 | 1,600,000 | $ 2,710.40 | $ 71,401.00 | $ 48,543.53 | $ 2,710.40 | 1791% | 1691% |
| **Ready Vehicle** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 8,822.00 | $ 71,401.00 | $ 2,669,894.30 | $ 8,822.00 | 30264% | 30164% |
| **Navigate** | 2 | 0 | 80 | 80 | 1,600,000 | $ 32,853.33 | $ 865,466.67 | $ 48,543.53 | $ 32,853.33 | 148% | 48% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 1,600,000 | $ 32,853.33 | $ 865,466.67 | $ 48,543.53 | $ 32,853.33 | 148% | 48% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 133,666.67 | $ 1,081,833.33 | $ 2,669,894.30 | $ 133,666.67 | 1997% | 1897% |
| **Stabilizing Treatment** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 133,666.67 | $ 1,081,833.33 | $ 2,669,894.30 | $ 133,666.67 | 1997% | 1897% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 1,600,000 | $ 82,133.33 | $ 2,163,666.67 | $ 48,543.53 | $ 82,133.33 | 59% | -41% |
| **Continuing Treatment** | 2 | 0 | 3520 | 3520 | 70,400,000 | $ 185,200.00 | $ 2,163,666.67 | $ 2,135,915.44 | $ 185,200.00 | 1153% | 1053% |
| **Patient Transfer** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 401,000.00 | $ 3,245,500.00 | $ 2,669,894.30 | $ 401,000.00 | 666% | 566% |
| **Document** | 2 | 0 | 3080 | 3080 | 61,600,000 | $ 216,200.00 | $ 3,245,500.00 | $ 1,868,926.01 | $ 216,200.00 | 864% | 764% |
| **Totals** | **2.000** | **0** | **24,600** | **24,600** | **492,000,000** | **$1,231,816.13** | **$14,927,136.33** | **$14,927,136.33** | **$1,231,816.13** | **40879%** | **39779%** |

Table 9. KVA "As Is" Low Volume Long Transport

| As Is Model: Driver | Volume(20000)Transport(20min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+ (#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 2 | 0 | 0% | 20000 | 0.0055 | $ 0.14 | $ - .0 | Turnout |
| **Determine Route** | 2 | | | 2 | 0 | 0% | 20000 | 0.0055 | $ 0.14 | $ - .0 | |
| **Ready Vehicle** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.0055 | $ 0.44 | $ - .0 | |
| **Navigate** | 2 | | | 2 | 0 | 0% | 20000 | 0.066666667 | $ 1.64 | $ - .0 | Travel |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 20000 | 0.066666667 | $ 1.64 | $ - .0 | |
| **Dev. Diff. Diagnosis** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 6.68 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 6.68 | $ - .0 | |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 20000 | 0.333333333 | $ 8.21 | $ - .0 | Transport |
| **Continuing Treatment** | | 1 | 2 | 3 | 0 | 0% | 20000 | 0.333333333 | $ 18.52 | $ - .0 | |
| **Patient Transfer** | | 3 | 2 | 5 | 0 | 0% | 20000 | 0.25 | $ 20.05 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 20000 | 0.25 | $ 10.81 | $ - .0 | Document |
| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
| **Map location** | 2 | 0 | 80 | 80 | 1,600,000 | $ 2,710.40 | $ 71,401.00 | $ 62,616.16 | $ 2,710.40 | 2310% | 2210% |
| **Determine Route** | 2 | 0 | 80 | 80 | 1,600,000 | $ 2,710.40 | $ 71,401.00 | $ 62,616.16 | $ 2,710.40 | 2310% | 2210% |
| **Ready Vehicle** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 8,822.00 | $ 71,401.00 | $ 3,443,888.88 | $ 8,822.00 | 39038% | 38938% |
| **Navigate** | 2 | 0 | 80 | 80 | 1,600,000 | $ 32,853.33 | $ 865,466.67 | $ 62,616.16 | $ 32,853.33 | 191% | 91% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 1,600,000 | $ 32,853.33 | $ 865,466.67 | $ 62,616.16 | $ 32,853.33 | 191% | 91% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 133,666.67 | $ 1,081,833.33 | $ 3,443,888.88 | $ 133,666.67 | 2576% | 2476% |
| **Stabilizing Treatment** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 133,666.67 | $ 1,081,833.33 | $ 3,443,888.88 | $ 133,666.67 | 2576% | 2476% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 1,600,000 | $ 164,266.67 | $ 4,327,333.33 | $ 62,616.16 | $ 164,266.67 | 38% | -62% |
| **Continuing Treatment** | 2 | 0 | 3520 | 3520 | 70,400,000 | $ 370,400.00 | $ 4,327,333.33 | $ 2,755,111.11 | $ 370,400.00 | 744% | 644% |
| **Patient Transfer** | 2 | 0 | 4400 | 4400 | 88,000,000 | $ 401,000.00 | $ 3,245,500.00 | $ 3,443,888.88 | $ 401,000.00 | 859% | 759% |
| **Document** | 2 | 0 | 3080 | 3080 | 61,600,000 | $ 216,200.00 | $ 3,245,500.00 | $ 2,410,722.22 | $ 216,200.00 | 1115% | 1015% |
| **Totals** | **2.000** | **0** | **24,600** | **24,600** | **492,000,000** | **$1,499,149.47** | **$19,254,469.67** | **$19,254,469.67** | **$1,499,149.47** | **51948%** | **50848%** |

Table 10. KVA “As Is” High Volume Short Transport

| As Is Model: Driver | Volume(40000)Transport(10min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+(#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 2 | 0 | 0% | 40000 | 0.0055 | $ 0.14 | $ - .0 | Turnout |
| **Determine Route** | 2 | | | 2 | 0 | 0% | 40000 | 0.0055 | $ 0.14 | $ - .0 | |
| **Ready Vehicle** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.0055 | $ 0.44 | $ - .0 | |
| **Navigate** | 2 | | | 2 | 0 | 0% | 40000 | 0.066666667 | $ 1.64 | $ - .0 | Travel |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 40000 | 0.066666667 | $ 1.64 | $ - .0 | |
| **Dev. Diff. Diagnosis** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 6.68 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 6.68 | $ - .0 | |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 40000 | 0.166666667 | $ 4.11 | $ - .0 | Transport |
| **Continuing Treatment** | | 1 | 2 | 3 | 0 | 0% | 40000 | 0.166666667 | $ 9.26 | $ - .0 | |
| **Patient Transfer** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.25 | $ 20.05 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 40000 | 0.25 | $ 10.81 | $ - .0 | Document |

| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Map location** | 2 | 0 | 80 | 80 | 3,200,000 | $ 5,420.80 | $ 142,802.00 | $ 97,087.07 | $ 5,420.80 | 1791% | 1691% |
| **Determine Route** | 2 | 0 | 80 | 80 | 3,200,000 | $ 5,420.80 | $ 142,802.00 | $ 97,087.07 | $ 5,420.80 | 1791% | 1691% |
| **Ready Vehicle** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 17,644.00 | $ 142,802.00 | $ 5,339,788.61 | $ 17,644.00 | 30264% | 30164% |
| **Navigate** | 2 | 0 | 80 | 80 | 3,200,000 | $ 65,706.67 | $ 1,730,933.33 | $ 97,087.07 | $ 65,706.67 | 148% | 48% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 3,200,000 | $ 65,706.67 | $ 1,730,933.33 | $ 97,087.07 | $ 65,706.67 | 148% | 48% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 267,333.33 | $ 2,163,666.67 | $ 5,339,788.61 | $ 267,333.33 | 1997% | 1897% |
| **Stabilizing Treatment** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 267,333.33 | $ 2,163,666.67 | $ 5,339,788.61 | $ 267,333.33 | 1997% | 1897% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 3,200,000 | $ 164,266.67 | $ 4,327,333.33 | $ 97,087.07 | $ 164,266.67 | 59% | -41% |
| **Continuing Treatment** | 2 | 0 | 3520 | 3520 | 140,800,000 | $ 370,400.00 | $ 4,327,333.33 | $ 4,271,830.89 | $ 370,400.00 | 1153% | 1053% |
| **Patient Transfer** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 802,000.00 | $ 6,491,000.00 | $ 5,339,788.61 | $ 802,000.00 | 666% | 566% |
| **Document** | 2 | 0 | 3080 | 3080 | 123,200,000 | $ 432,400.00 | $ 6,491,000.00 | $ 3,737,852.02 | $ 432,400.00 | 864% | 764% |
| **Totals** | **2.000** | **0** | **24,600** | **24,600** | **984,000,000** | **$2,463,632.27** | **$29,854,272.67** | **$29,854,272.67** | **$2,463,632.27** | **40879%** | **39779%** |

Table 11. KVA "As Is" High Volume Long Transport

| As Is Model: Driver | Volume(40000)Transport(20min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+ (#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 2 | 0 | 0% | 40000 | 0.0055 | $ 0.14 | $ - .0 | Turnout |
| **Determine Route** | 2 | | | 2 | 0 | 0% | 40000 | 0.0055 | $ 0.14 | $ - .0 | |
| **Ready Vehicle** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.0055 | $ 0.44 | $ - .0 | |
| **Navigate** | 2 | | | 2 | 0 | 0% | 40000 | 0.066666667 | $ 1.64 | $ - .0 | Travel |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 40000 | 0.066666667 | $ 1.64 | $ - .0 | |
| **Dev. Diff. Diagnosis** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 6.68 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 6.68 | $ - .0 | |
| **Pilot vehicle** | 2 | | | 2 | 0 | 0% | 40000 | 0.333333333 | $ 8.21 | $ - .0 | Transport |
| **Continuing Treatment** | | 1 | 2 | 3 | 0 | 0% | 40000 | 0.333333333 | $ 18.52 | $ - .0 | |
| **Patient Transfer** | | 3 | 2 | 5 | 0 | 0% | 40000 | 0.25 | $ 20.05 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 40000 | 0.25 | $ 10.81 | $ - .0 | Document |
| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
| **Map location** | 2 | 0 | 80 | 80 | 3,200,000 | $ 5,420.80 | $ 142,802.00 | $ 125,232.32 | $ 5,420.80 | 2310% | 2210% |
| **Determine Route** | 2 | 0 | 80 | 80 | 3,200,000 | $ 5,420.80 | $ 142,802.00 | $ 125,232.32 | $ 5,420.80 | 2310% | 2210% |
| **Ready Vehicle** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 17,644.00 | $ 142,802.00 | $ 6,887,777.77 | $ 17,644.00 | 39038% | 38938% |
| **Navigate** | 2 | 0 | 80 | 80 | 3,200,000 | $ 65,706.67 | $ 1,730,933.33 | $ 125,232.32 | $ 65,706.67 | 191% | 91% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 3,200,000 | $ 65,706.67 | $ 1,730,933.33 | $ 125,232.32 | $ 65,706.67 | 191% | 91% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 267,333.33 | $ 2,163,666.67 | $ 6,887,777.77 | $ 267,333.33 | 2576% | 2476% |
| **Stabilizing Treatment** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 267,333.33 | $ 2,163,666.67 | $ 6,887,777.77 | $ 267,333.33 | 2576% | 2476% |
| **Pilot vehicle** | 2 | 0 | 80 | 80 | 3,200,000 | $ 328,533.33 | $ 8,654,666.67 | $ 125,232.32 | $ 328,533.33 | 38% | -62% |
| **Continuing Treatment** | 2 | 0 | 3520 | 3520 | 140,800,000 | $ 740,800.00 | $ 8,654,666.67 | $ 5,510,222.21 | $ 740,800.00 | 744% | 644% |
| **Patient Transfer** | 2 | 0 | 4400 | 4400 | 176,000,000 | $ 802,000.00 | $ 6,491,000.00 | $ 6,887,777.77 | $ 802,000.00 | 859% | 759% |
| **Document** | 2 | 0 | 3080 | 3080 | 123,200,000 | $ 432,400.00 | $ 6,491,000.00 | $ 4,821,444.44 | $ 432,400.00 | 1115% | 1015% |
| **Totals** | **2.000** | **0** | **24,600** | **24,600** | **984,000,000** | **$2,998,298.93** | **$38,508,939.33** | **$38,508,939.33** | **$2,998,298.93** | **51948%** | **50848%** |

# APPENDIX B. KVA APPLIED TO THE "TO BE" MODEL

Table 12. KVA "To Be" Low Volume Short Transport

| To Be Model: AV | Volume(20000)Transport(10min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+ (#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 1 | 1 | 100% | 20000 | 0.0055 | $ 0.07 | $ 0.070 | Turnout |
| **Determine Route** | 2 | | | 1 | 1 | 100% | 20000 | 0.0055 | $ 0.07 | $ 0.070 | |
| **Ready Vehicle** | | 2 | 3 | 5 | 0 | 0% | 20000 | 0.0055 | $ 0.49 | $ - .0 | |
| **Navigate** | 2 | | | 1 | 1 | 100% | 20000 | 0.066666667 | $ 0.82 | $ 0.070 | Travel |
| **Pilot vehicle** | 2 | | | 1 | 1 | 100% | 20000 | 0.066666667 | $ 0.82 | $ 0.070 | |
| **Dev. Diff. Diagnosis** | | 2 | 3 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 7.46 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 2 | 3 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 7.46 | $ - .0 | |
| **Pilot vehicle** | 1 | | | 0 | 1 | 100% | 20000 | 0.166666667 | $ - | $ 0.070 | Transport |
| **Continuing Treatment** | | | 2 | 2 | 0 | 0% | 20000 | 0.166666667 | $ 7.21 | $ - .0 | |
| **Patient Transfer** | | | 2 | 2 | 0 | 0% | 20000 | 0.25 | $ 10.81 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 20000 | 0.25 | $ 10.81 | $ - .0 | Document |
| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
| **Map location** | 2 | 40 | 80 | 120 | 2,400,000 | $ 2,755.20 | $ 71,401.00 | $ 68,108.61 | $ 2,755.20 | 2472% | 2372% |
| **Determine Route** | 2 | 40 | 80 | 120 | 2,400,000 | $ 2,755.20 | $ 71,401.00 | $ 68,108.61 | $ 2,755.20 | 2472% | 2372% |
| **Ready Vehicle** | 2 | 0 | 5500 | 5500 | 110,000,000 | $ 9,845.00 | $ 71,401.00 | $ 3,121,644.48 | $ 9,845.00 | 31708% | 31608% |
| **Navigate** | 2 | 40 | 80 | 120 | 2,400,000 | $ 17,826.67 | $ 865,466.67 | $ 68,108.61 | $ 17,826.67 | 382% | 282% |
| **Pilot vehicle** | 2 | 40 | 80 | 120 | 2,400,000 | $ 17,826.67 | $ 865,466.67 | $ 68,108.61 | $ 17,826.67 | 382% | 282% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 5500 | 5500 | 110,000,000 | $ 149,166.67 | $ 1,081,833.33 | $ 3,121,644.48 | $ 149,166.67 | 2093% | 1993% |
| **Stabilizing Treatment** | 2 | 0 | 5500 | 5500 | 110,000,000 | $ 149,166.67 | $ 1,081,833.33 | $ 3,121,644.48 | $ 149,166.67 | 2093% | 1993% |
| **Pilot vehicle** | 1 | 40 | 40 | 80 | 1,600,000 | $ 1,400.00 | $ 2,163,666.67 | $ 45,405.74 | $ 1,400.00 | 3243% | 3143% |
| **Continuing Treatment** | 1 | 0 | 3080 | 3080 | 61,600,000 | $ 144,133.33 | $ 2,163,666.67 | $ 1,748,120.91 | $ 144,133.33 | 1213% | 1113% |
| **Patient Transfer** | 1 | 0 | 3080 | 3080 | 61,600,000 | $ 216,200.00 | $ 3,245,500.00 | $ 1,748,120.91 | $ 216,200.00 | 809% | 709% |
| **Document** | 1 | 0 | 3080 | 3080 | 61,600,000 | $ 216,200.00 | $ 3,245,500.00 | $ 1,748,120.91 | $ 216,200.00 | 809% | 709% |
| **Totals** | **1.636** | **200** | **26,100** | **26,300** | **526,000,000** | **$927,275.40** | **$14,927,136.33** | **$14,927,136.33** | **$927,275.40** | **47675%** | **46575%** |

Table 13. KVA "To Be" Low Volume Long Transport

| To Be Model: AV | Volume(20000)Transport(20min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+(#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 1 | 1 | 100% | 20000 | 0.0055 | $ 0.07 | $ 0.070 | Turnout |
| **Determine Route** | 2 | | | 1 | 1 | 100% | 20000 | 0.0055 | $ 0.07 | $ 0.070 | |
| **Ready Vehicle** | | 2 | 3 | 5 | 0 | 0% | 20000 | 0.0055 | $ 0.49 | $ - .0 | |
| **Navigate** | 2 | | | 1 | 1 | 100% | 20000 | 0.066666667 | $ 0.82 | $ 0.070 | Travel |
| **Pilot vehicle** | 2 | | | 1 | 1 | 100% | 20000 | 0.066666667 | $ 0.82 | $ 0.070 | |
| **Dev. Diff. Diagnosis** | | 2 | 3 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 7.46 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 2 | 3 | 5 | 0 | 0% | 20000 | 0.083333333 | $ 7.46 | $ - .0 | |
| **Pilot vehicle** | 1 | | | 0 | 1 | 100% | 20000 | 0.333333333 | $ - | $ 0.070 | Transport |
| **Continuing Treatment** | | | 2 | 2 | 0 | 0% | 20000 | 0.333333333 | $ 14.41 | $ - .0 | |
| **Patient Transfer** | | | 2 | 2 | 0 | 0% | 20000 | 0.25 | $ 10.81 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 20000 | 0.25 | $ 10.81 | $ - .0 | Document |
| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
| **Map location** | 2 | 40 | 80 | 120 | 2,400,000 | $ 2,755.20 | $ 71,401.00 | $ 87,853.09 | $ 2,755.20 | 3189% | 3089% |
| **Determine Route** | 2 | 40 | 80 | 120 | 2,400,000 | $ 2,755.20 | $ 71,401.00 | $ 87,853.09 | $ 2,755.20 | 3189% | 3089% |
| **Ready Vehicle** | 2 | 0 | 5500 | 5500 | 110,000,000 | $ 9,845.00 | $ 71,401.00 | $ 4,026,600.12 | $ 9,845.00 | 40900% | 40800% |
| **Navigate** | 2 | 40 | 80 | 120 | 2,400,000 | $ 17,826.67 | $ 865,466.67 | $ 87,853.09 | $ 17,826.67 | 493% | 393% |
| **Pilot vehicle** | 2 | 40 | 80 | 120 | 2,400,000 | $ 17,826.67 | $ 865,466.67 | $ 87,853.09 | $ 17,826.67 | 493% | 393% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 5500 | 5500 | 110,000,000 | $ 149,166.67 | $ 1,081,833.33 | $ 4,026,600.12 | $ 149,166.67 | 2699% | 2599% |
| **Stabilizing Treatment** | 2 | 0 | 5500 | 5500 | 110,000,000 | $ 149,166.67 | $ 1,081,833.33 | $ 4,026,600.12 | $ 149,166.67 | 2699% | 2599% |
| **Pilot vehicle** | 1 | 40 | 40 | 80 | 1,600,000 | $ 1,400.00 | $ 4,327,333.33 | $ 58,568.73 | $ 1,400.00 | 4183% | 4083% |
| **Continuing Treatment** | 1 | 0 | 3080 | 3080 | 61,600,000 | $ 288,266.67 | $ 4,327,333.33 | $ 2,254,896.07 | $ 288,266.67 | 782% | 682% |
| **Patient Transfer** | 1 | 0 | 3080 | 3080 | 61,600,000 | $ 216,200.00 | $ 3,245,500.00 | $ 2,254,896.07 | $ 216,200.00 | 1043% | 943% |
| **Document** | 1 | 0 | 3080 | 3080 | 61,600,000 | $ 216,200.00 | $ 3,245,500.00 | $ 2,254,896.07 | $ 216,200.00 | 1043% | 943% |
| **Totals** | **1.636** | **200** | **26,100** | **26,300** | **526,000,000** | **$1,071,408.73** | **$19,254,469.67** | **$19,254,469.67** | **$1,071,408.73** | **60713%** | **59613%** |

Table 14. KVA “To Be High Volume Short Transport

| To Be Model: AV | Volume(40000)Transport(10min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Process Description | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+(#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| Map location | 2 | | | 1 | 1 | 100% | 40000 | 0.0055 | $ 0.07 | $ 0.035 | Turnout |
| Determine Route | 2 | | | 1 | 1 | 100% | 40000 | 0.0055 | $ 0.07 | $ 0.035 | |
| Ready Vehicle | | 2 | 3 | 5 | 0 | 0% | 40000 | 0.0055 | $ 0.49 | $ - .0 | |
| Navigate | 2 | | | 1 | 1 | 100% | 40000 | 0.066666667 | $ 0.82 | $ 0.035 | Travel |
| Pilot vehicle | 2 | | | 1 | 1 | 100% | 40000 | 0.066666667 | $ 0.82 | $ 0.035 | |
| Dev. Diff. Diagnosis | | 2 | 3 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 7.46 | $ - .0 | Treatment |
| Stabilizing Treatment | | 2 | 3 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 7.46 | $ - .0 | |
| Pilot vehicle | 1 | | | 0 | 1 | 100% | 40000 | 0.166666667 | $ - | $ 0.035 | Transport |
| Continuing Treatment | | | 2 | 2 | 0 | 0% | 40000 | 0.166666667 | $ 7.21 | $ - .0 | |
| Patient Transfer | | | 2 | 2 | 0 | 0% | 40000 | 0.25 | $ 10.81 | $ - .0 | Report |
| Document | | | 2 | 2 | 0 | 0% | 40000 | 0.25 | $ 10.81 | $ - .0 | Document |
| Process Description | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
| Map location | 2 | 40 | 80 | 120 | 4,800,000 | $ 4,110.40 | $ 142,802.00 | $ 136,217.21 | $ 4,110.40 | 3314% | 3214% |
| Determine Route | 2 | 40 | 80 | 120 | 4,800,000 | $ 4,110.40 | $ 142,802.00 | $ 136,217.21 | $ 4,110.40 | 3314% | 3214% |
| Ready Vehicle | 2 | 0 | 5500 | 5500 | 220,000,000 | $ 19,690.00 | $ 142,802.00 | $ 6,243,288.96 | $ 19,690.00 | 31708% | 31608% |
| Navigate | 2 | 40 | 80 | 120 | 4,800,000 | $ 34,253.33 | $ 1,730,933.33 | $ 136,217.21 | $ 34,253.33 | 398% | 298% |
| Pilot vehicle | 2 | 40 | 80 | 120 | 4,800,000 | $ 34,253.33 | $ 1,730,933.33 | $ 136,217.21 | $ 34,253.33 | 398% | 298% |
| Dev. Diff. Diagnosis | 2 | 0 | 5500 | 5500 | 220,000,000 | $ 298,333.33 | $ 2,163,666.67 | $ 6,243,288.96 | $ 298,333.33 | 2093% | 1993% |
| Stabilizing Treatment | 2 | 0 | 5500 | 5500 | 220,000,000 | $ 298,333.33 | $ 2,163,666.67 | $ 6,243,288.96 | $ 298,333.33 | 2093% | 1993% |
| Pilot vehicle | 1 | 40 | 40 | 80 | 3,200,000 | $ 1,400.00 | $ 4,327,333.33 | $ 90,811.48 | $ 1,400.00 | 6487% | 6387% |
| Continuing Treatment | 1 | 0 | 3080 | 3080 | 123,200,000 | $ 288,266.67 | $ 4,327,333.33 | $ 3,496,241.82 | $ 288,266.67 | 1213% | 1113% |
| Patient Transfer | 1 | 0 | 3080 | 3080 | 123,200,000 | $ 432,400.00 | $ 6,491,000.00 | $ 3,496,241.82 | $ 432,400.00 | 809% | 709% |
| Document | 1 | 0 | 3080 | 3080 | 123,200,000 | $ 432,400.00 | $ 6,491,000.00 | $ 3,496,241.82 | $ 432,400.00 | 809% | 709% |
| Totals | **1.636** | **200** | **26,100** | **26,300** | **1,052,000,000** | **$1,847,550.80** | **$29,854,272.67** | **$29,854,272.67** | **$1,847,550.80** | **52633%** | **51533%** |

Table 15. KVA “To Be” High Volume Long Transport

| To Be Model: AV | Volume(40000)Transport(20min) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Process Description** | #Drivers or AVs | #EMTs | #Medics | Total # of Employees Performing the Subprocess | Total # of Automated Equivalents (AE) Performing the Subprocess | Percent (%) Subprocess Automated (PA) | EMS calls: Times Performed In a Year (TPY) | Average Time to Complete (ATC) hrs | Average Labor Cost Per Subprocess (ALCS) =((#EMTs*$12.32)+ (#Medics*$21.62)* ATC Note: Zero if 100% automated | Automation Cost (AC) = (Total Cost of Ownership Per Year ($7000)/TPY) / # of Subprocesses Involved | |
| **Map location** | 2 | | | 1 | 1 | 100% | 40000 | 0.0055 | $ 0.07 | $ 0.035 | Turnout |
| **Determine Route** | 2 | | | 1 | 1 | 100% | 40000 | 0.0055 | $ 0.07 | $ 0.035 | |
| **Ready Vehicle** | | 2 | 3 | 5 | 0 | 0% | 40000 | 0.0055 | $ 0.49 | $ - .0 | |
| **Navigate** | 2 | | | 1 | 1 | 100% | 40000 | 0.066666667 | $ 0.82 | $ 0.035 | Travel |
| **Pilot vehicle** | 2 | | | 1 | 1 | 100% | 40000 | 0.066666667 | $ 0.82 | $ 0.035 | |
| **Dev. Diff. Diagnosis** | | 2 | 3 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 7.46 | $ - .0 | Treatment |
| **Stabilizing Treatment** | | 2 | 3 | 5 | 0 | 0% | 40000 | 0.083333333 | $ 7.46 | $ - .0 | |
| **Pilot vehicle** | 1 | | | 0 | 1 | 100% | 40000 | 0.333333333 | $ - | $ 0.035 | Transport |
| **Continuing Treatment** | | | 2 | 2 | 0 | 0% | 40000 | 0.333333333 | $ 14.41 | $ - .0 | |
| **Patient Transfer** | | | 2 | 2 | 0 | 0% | 40000 | 0.25 | $ 10.81 | $ - .0 | Report |
| **Document** | | | 2 | 2 | 0 | 0% | 40000 | 0.25 | $ 10.81 | $ - .0 | Document |

| **Process Description** | # of EMS Units Required = Sum / Subprocesses | Automated Learning Time (LT) Equivalent (ALTE) In Hrs = AE*PA*40 | Human Learning Time (HLT) for subprocess in Hrs: Drivers =40hrs, EMTs = 440hrs, Medics = 1540hrs | Single Execution of a Subprocess Learning Time In Hrs (SESLT) = ALTE + HLT | Total Learning Time Units (TLTU) Per Year =SESLT * TPY | Subprocess Personnel & AE Cost Per Year = (ALCS+AC)*TPY | "Off The Shelf" Personnel & AE Price Per Year = ($649.10 * Call Volume) *Subprocess time | ROI and monetized ROK **Numerator** = TLTU * (Process Price Per Year/Summed TLTU) | ROI and ROK **Denominator** = Cost Per Year | ROK = Numerator / Denominator | ROI= (Numerator - Denominator) / Denominator |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Map location** | 2 | 40 | 80 | 120 | 4,800,000 | $ 4,110.40 | $ 142,802.00 | $ 175,706.19 | $ 4,110.40 | 4275% | 4175% |
| **Determine Route** | 2 | 40 | 80 | 120 | 4,800,000 | $ 4,110.40 | $ 142,802.00 | $ 175,706.19 | $ 4,110.40 | 4275% | 4175% |
| **Ready Vehicle** | 2 | 0 | 5500 | 5500 | 220,000,000 | $ 19,690.00 | $ 142,802.00 | $ 8,053,200.24 | $ 19,690.00 | 40900% | 40800% |
| **Navigate** | 2 | 40 | 80 | 120 | 4,800,000 | $ 34,253.33 | $ 1,730,933.33 | $ 175,706.19 | $ 34,253.33 | 513% | 413% |
| **Pilot vehicle** | 2 | 40 | 80 | 120 | 4,800,000 | $ 34,253.33 | $ 1,730,933.33 | $ 175,706.19 | $ 34,253.33 | 513% | 413% |
| **Dev. Diff. Diagnosis** | 2 | 0 | 5500 | 5500 | 220,000,000 | $ 298,333.33 | $ 2,163,666.67 | $ 8,053,200.24 | $ 298,333.33 | 2699% | 2599% |
| **Stabilizing Treatment** | 2 | 0 | 5500 | 5500 | 220,000,000 | $ 298,333.33 | $ 2,163,666.67 | $ 8,053,200.24 | $ 298,333.33 | 2699% | 2599% |
| **Pilot vehicle** | 1 | 40 | 40 | 80 | 3,200,000 | $ 1,400.00 | $ 8,654,666.67 | $ 117,137.46 | $ 1,400.00 | 8367% | 8267% |
| **Continuing Treatment** | 1 | 0 | 3080 | 3080 | 123,200,000 | $ 576,533.33 | $ 8,654,666.67 | $ 4,509,792.13 | $ 576,533.33 | 782% | 682% |
| **Patient Transfer** | 1 | 0 | 3080 | 3080 | 123,200,000 | $ 432,400.00 | $ 6,491,000.00 | $ 4,509,792.13 | $ 432,400.00 | 1043% | 943% |
| **Document** | 1 | 0 | 3080 | 3080 | 123,200,000 | $ 432,400.00 | $ 6,491,000.00 | $ 4,509,792.13 | $ 432,400.00 | 1043% | 943% |
| Totals | **1.636** | **200** | **26,100** | **26,300** | **1,052,000,000** | **$2,135,817.47** | **$38,508,939.33** | **$38,508,939.33** | **$2,135,817.47** | **67109%** | **66009%** |

# LIST OF REFERENCES


3M. “What Is Vehicle-to-Infrastructure (V2I) Communication and Why Do We Need It?” Accessed December 7, 2019. https://www.3m.com/wps/portal/en_US/3M/road-safety-us/resources/road-transportation-safety-center-blog/full-story/~/what-is-vehicle-to-infrastructure-v2i-communication-and-why-do-we-need-it/?storyid=021748d7-f48c-4cd8-8948-b7707f231795.

101 Computing. “Input-Process-Output. May 14, 2018. https://www.101computing.net/original-price-calculator/input-process-output/.

911 Dispatcher EDU. “Job Duties of 911 Dispatchers.” Accessed December 7, 2019. https://www.911dispatcheredu.org/job-description/.

Alender, Sarah. “Elon Musk Thinks Cars You Can Drive Might Be Outlawed Someday.” *Wall Street Insanity* (blog), March 18, 2015. https://wallstreetinsanity.com/elon-musk-thinks-cars-you-can-drive-might-be-outlawed-someday/.

American Medical Response. “Solutions: Who We Help.” Accessed December 6, 2019. https://www.amr.net/solutions.

Association of Public-Safety Communications Officials International. “Emergency Medical Dispatch (EMD).” Accessed December 7, 2019. https://www.apcointl.org/training-and-certification/disciplines/emergency-medical-dispatch-emd/.

Austin Center for Design. “Wicked Problems.” Accessed December 7, 2019. https://www.wickedproblems.com/1_wicked_problems.php.

Boudette, Neal E. “Tesla Upgrades Autopilot in Cars on the Road.” *New York Times*, September 23, 2016. https://www.nytimes.com/2016/09/24/business/tesla-upgrades-autopilot-in-cars-on-the-road.html.

Brindel, Beth. “What’s a Disruptive Technology?” How Stuff Works, November 1, 2014, https://electronics.howstuffworks.com/everyday-tech/what-is-disruptive-technology.htm.

Bucher, Joshua, and Hashim Zaidi. “A Brief History of Emergency Medical Services in the United States.” Emergency Medicine Residents’ Association. Accessed February 9, 2019. http://www.emra.org/about-emra/history/ems-history/.

Chapman, Susan, Vanessa Lindler, and Jennifer Kaiser. *The Emergency Medical Services Workforce Agenda for the Future*. Washington, DC: National Highway Traffic Safety Administration, 2011. https://www.ems.gov/pdf/2011/EMS_Workforce_Agenda_052011.pdf.

Cintron, Jose. “A Framework for Measuring the Value-Added of Knowledge Processes with Analysis of Process Interactions and Dynamics.” PhD diss., University of Central Florida, 2013. http://stars.library.ucf.edu/cgi/viewcontent.cgi?article=3739&context=etd.

City of Lakeland. *Budget Overview*. Lakeland, FL: City of Lakeland, 2019. https://www.lakelandgov.net/media/8683/section-b-budget-overview.pdf.

Clawson, Jeff. “EMS Dispatch.” *Anesthesia Key* (blog), June 14, 2016. https://aneskey.com/ems-dispatch/.

Davies, Alex. “Inside the Races That Jump-Started the Self-Driving Car.” *Wired*, November 10, 2017. https://www.wired.com/story/darpa-grand-urban-challenge-self-driving-car/.

Defense Advanced Research Projects Agency. “The DARPA Grand Challenge: Ten Years Later.” March 13, 2014. https://www.darpa.mil/news-events/2014-03-13.

Enwemeka, Zenajor. “Consumers Don’t Really Want Self-Driving Cars, MIT Study Finds.” WBUR Boston, May 25, 2017. https://www.wbur.org/bostonomix/2017/05/25/mit-study-self-driving-cars.

Eschmann, Nicholas M., Ronald G. Pirrallo, Tom P. Aufderheide, and E. Brooke Lerner. “The Association between Emergency Medical Services Staffing Patterns and Out-of-Hospital Cardiac Arrest Survival.” *Prehospital Emergency Care* 14, no. 1 (January 2010): 71–77. https://doi.org/10.3109/10903120903349820.

Faris, Maranda. “As Medicine, Nursing Careers Call, Fewer People Want to Work on EMS Crews in Western Tennessee.” *Jackson Sun*, July 14, 2017. https://www.jacksonsun.com/story/news/local/2017/07/14/addressing-ems-shortages/467507001/.

Fowler, Floyd. *Survey Research Methods*. 4th ed. Thousand Oaks, CA: SAGE Publications, 2009. https://doi.org/10.4135/9781452230184.

Frampton, Rob. “Company Officer Leadership: Fire-Based EMS Systems.” International Association of Fire Chiefs, May 4, 2017. https://www.iafc.org/on-scene/on-scene-article/company-officer-leadership-fire-based-ems-systems.

Grayson, Kelly. “EMS 2.0: The Logistics of Change.” EMS1, March 11, 2010. https://www.ems1.com/archive/articles/ems-20-the-logistics-of-change-yqzT26TIxusme7Gk/.

Hancock, Peter. “Are Autonomous Cars Really Safer Than Human Drivers?” *Scientific American*, February 3, 2018. https://www.scientificamerican.com/article/are-autonomous-cars-really-safer-than-human-drivers/.

Housel, Thomas J., Omar El Sawy, Jiangfan Zhong, and Waymond Rodgers. "Measuring the Return on Knowledge Embedded in Information Technology." In *Proceedings of the 22nd International Conference on Information Systems*, 97–106. Atlanta: Association for Information Systems, 2001. https://pdfs.semanticscholar.org/ee4d/64c897abae1e4f62ebfc4f4d880cc2847568.pdf.

Housel, Thomas J., and Valery Kanevsky. "Measuring the Value Added of Management: A Knowledge Value Added Approach." NPS-AM-06-056. Monterey, CA: Naval Postgraduate School, December 31, 2006. https://doi.org/10.21236/ADA496651.

Huang, Sam. "How the Autonomous Car Works: A Technology Overview." *Medium* (blog), April 25, 2018. https://medium.com/@thewordofsam/how-the-autonomous-car-works-a-technology-overview-5c1ac468606f.

International Association of Fire Fighters. "Fire Service-Based EMS Electronic Tool Kit." Washington, DC: International Association of Fire Fighters, 2013. https://www.nfpa.org/-/media/Files/Membership/member-sections/Metro-Chiefs/FSBased-EMS-Tool-Kit-2013.ashx?la=en.

———. *Handbook on Mobile Integrated Healthcare*. Chantilly, VA: International Association of Fire Chiefs, 2017. https://www.iafc.org/docs/default-source/1ems/iafchandbookformih.pdf?sfvrsn=aa44b30d_0.

———. "IAFF Opposes Creation of Separate EMS Administration." Accessed February 9, 2019. https://www.fireengineering.com/articles/2005/06/iaff-opposes-creation-of-separate-ems-administration.html.

———. "Position Statement: Fire-Based Emergency Medical Services." Washington, DC: International Association of Fire Chiefs, May 7, 2009. https://www.iafc.org/about-iafc/positions/position/iafc-position-fire-based-emergency-medical-services.

International Engineering Consortium. "Knowledge Value-Added (KVA) Methodology." Chicago: International Engineering Consortium, 2019. http://cmapspublic3.ihmc.us/rid=1G9L62WTW-NJ5G5D-C84/KVAmethodology.pdf.

*IoT for All*. "How Do Self-Driving Cars Work?" October 1, 2018. https://www.iotforall.com/how-do-self-driving-cars-work/.

Journal of Emergency Management Services. "Skip Kirkwood." Accessed March 17, 2019. https://www.jems.com/authors/q-t/skip-kirkwood-ms-jd-emt-p-efo.html.

Kannan, Gopika, and K. B. Akhilesh. "Human Capital Knowledge Value Added: A Case Study in Infotech." *Journal of Intellectual Capital* 3, no. 2 (2002): 167–79. https://doi.org/10.1108/14691930210424752.

Kemp, Mac. “EMS and Homeland Security.” *Homeland Security Affairs*, June 10, 2014. https://www.hsaj.org/articles/262.

Kenton, Will. “T-Test Definition.” Investopedia. Accessed November 2, 2019. https://www.investopedia.com/terms/t/t-test.asp.

Koh, Hian Chye, and Khim Ling Sim. “Balanced Scorecard: A Rising Trend in Strategic Performance Measurement.” *Measuring Business Excellence* 5, no. 2 (2001): 18–27. https://doi.org/10.1108/13683040110397248.

LaRocca, Scott H. “Knowledge Value Added (KVA) Methodology as a Tool for Measuring the Utilization of Knowledge Assets aboard Marine Corps Installations.” Master’s thesis, Naval Postgraduate School, 2008. https://calhoun.nps.edu/handle/10945/4118.

LaValle, Steven M., and James J. Kuffner Jr. “Rapidly-Exploring Random Trees: Progress and Prospects.” In *Algorithmic and Computational Robotics: New Directions*, 293–308. Boca Raton, FL: CRC Press, 2001.

Li, Ming, and Paul Vitanyi. *An Introduction to Kolmogorov Complexity and Its Applications*. 3rd ed. New York: Springer, 2008.

Mankins, John C. “Technology Readiness Assessments: A Retrospective.” *Acta Astronautica* 65, no. 9 (2009): 1216–23. https://doi.org/10.1016/j.actaastro.2009.03.058.

Marks, Jason. “What Software Do Autonomous Vehicle Engineers Use? Part 1/2.” *Medium* (blog), June 25, 2018. https://medium.com/@olley_io/what-software-do-autonomous-vehicle-engineers-use-part-1-2-275631071199.

MathWorks. “Object Recognition.” Accessed December 7, 2019. https://www.mathworks.com/solutions/deep-learning/object-recognition.html.

McLellan, Charles. “What Is V2X Communication? Creating Connectivity for the Autonomous Car Era.” ZDNet, November 4, 2019. https://www.zdnet.com/article/what-is-v2x-communication-creating-connectivity-for-the-autonomous-car-era/.

Morgan, Jacob. “A Simple Explanation of ‘the Internet of Things.’” *Forbes*, May 13, 2014. https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/.

National Emergency Medical Services Information System. “EMS Data Cube.” Accessed October 9, 2019. https://rp.nemsis.org/reportportal/design/view.aspx.

National Fire Protection Association. “Fire Department Calls.” Last modified November 2019. https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Fire-department-calls.

———. *Standard for a Fire and Emergency Service Vehicle Operations Training Program*. NFPA 1451. Quincy, MA: National Fire Protection Association, 2018. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1451.

———. *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*. NFPA 1710. Quincy, MA: National Fire Protection Association, 2016. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1710.

National Highway Traffic Safety Administration. “Automated Vehicles for Safety.” Accessed December 7, 2019. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety.

———. *Emergency Medical Services Agenda for the Future*. Washington, DC: National Highway Traffic Safety Administration, 1996. https://one.nhtsa.gov/people/injury/ems/agenda/emsman.html.

———. “EMS Research.” Accessed December 7, 2019. https://www.ems.gov/research.html.

———. *National EMS Scope of Practice Model*. Washington, DC: National Highway Traffic Safety Administration, 2007. https://www.ems.gov/education/EMSScope.pdf.

———. “Preliminary Statement of Policy Concerning Automated Vehicles.” Washington, DC: National Highway Traffic Safety Administration, 2013. https://itlaw.wikia.org/wiki/Preliminary_Statement_of_Policy_Concerning_Automated_Vehicles.

National Oceanic and Atmospheric Administration. “What Is LIDAR?” Accessed December 7, 2019. https://oceanservice.noaa.gov/facts/lidar.html.

National Research Council. *Accidental Death and Disability: The Neglected Disease of Modern Society*. Washington, DC: National Research Council, 1966. https://www.ems.gov/pdf/1997-Reproduction-AccidentalDeathDissability.pdf.

Nelson, Kristi. “Emergency Wait: Local Ambulance Crews Face Challenges with Crowded ERs, EMT Shortage.” *Knoxville News Sentinel*, January 9, 2019, https://www.knoxnews.com/story/news/health/2019/01/09/ambulances-wait-times-hospitals-crowded-ers-emt-shortages/2514188002/.

Nevitt, Cindy. “Cost of Government: Most Tax Dollars Go toward Salaries & Healthcare.” *Press of Atlantic City*, March 24, 2015. https://www.pressofatlanticcity.com/news/breaking/cost-of-government-most-tax-dollars-go-toward-salaries-healthcare/article_23f00e24-cef0-11e4-bfa7-7b06dcd8f32b.html.

*New York Times*. “How Driverless Cars See the World around Them.” March 19, 2018. https://www.nytimes.com/2018/03/19/technology/how-driverless-cars-work.html.

Persse, David, and Katarzyna Kimmel. “Background and Advantages of a Tiered EMS Response in a Large, Fire-Based EMS Model.” *Health Care: Current Reviews* 3, no. 1 (2015). https://doi.org/10.4172/2375-4273.1000138.

Pratt, Franklin D., Steven Katz, Paul E. Pepe, and David Persse. *Prehospital 9-1-1 Emergency Medical Response: The Role of the United States Fire Service in Delivery and Coordination*. Washington, DC: International Association of Fire Fighters, July 5, 2007. https://services.prod.iaff.org/ContentFile/Get/17079.

Purvis. “Computer Aided Dispatch Flowchart.” Accessed September 1, 2019. https://www.purvis.com/what-we-do/fire-station-alerting/.

Rastogi, Ankit. “A Brief Introduction to Lean, Six Sigma and Lean Six Sigma.” Grey Campus, March 12, 2018. https://www.greycampus.com/blog/quality-management/a-brief-introduction-to-lean-and-six-sigma-and-lean-six-sigma.

Rogers, Kara. “Battlefield Medicine: The Golden Hour and the Platinum Ten.” *Encyclopedia Britannica Blog*, June 23, 2011. http://blogs.britannica.com/2011/06/battlefield-medicine-golden-hour-platinum-ten/.

Saunders, Jim. “Florida’s Population Climbs, Now Third Most-Populous State.” *Northwest Florida Daily News*, February 18, 2019. https://www.nwfdailynews.com/news/20181219/floridas-population-climbs-now-third-most-populous-state.

Shotwell, David, Mark Merlin, and Vincent Robbins. “Ambulance Crew Configuration: Are Two Paramedics Better Than One?” JEMS, October 8, 2018. https://www.jems.com/2018/10/08/ambulance-crew-configuration-are-two-paramedics-better-than-one/.

Smart, P. Andi, Roger S. Maull, Abed Al-Fatah Karasneh, Zoe J. Radnor, and Thomas J. Housel. “An Approach for Identifying Value in Business Processes.” *Journal of Knowledge Management* 7, no. 4 (2003): 49–61. https://doi.org/10.1108/13673270310492949.

Snyder, Kate. “Ambulance Services Face National Paramedic Shortage.” EMS1, March 28, 2019. https://www.ems1.com/paramedic-jobs-and-careers/articles/393665048-Ambulance-services-face-national-paramedic-shortage/.

Taghizadegan, Salman. *Mastering Lean Six Sigma: Advanced Black Belt Concepts*. New York: Momentum Press, 2013. ProQuest.

Union of Concerned Scientists. “Self-Driving Cars Explained.” February 21, 2018. https://www.ucsusa.org/clean-vehicles/how-self-driving-cars-work.

Voelcker, John. “Autonomous Vehicles Complete DARPA Urban Challenge.” IEEE Spectrum, November 1, 2007. https://spectrum.ieee.org/transportation/advanced-cars/autonomous-vehicles-complete-darpa-urban-challenge.

Volunteer Firemen’s Insurance Service. “Emergency Vehicle Operations Course.” York, PA: Volunteer Firemen’s Insurance Service, 2019.

Williams, Matthew. “The Drive for Autonomous Vehicles: The DARPA Grand Challenge.” Herox. Accessed December 7, 2019. https://www.herox.com/crowdsourcing-news/159-the-drive-for-autonomous-vehicles-the-darpa-grand.

THIS PAGE INTENTIONALLY LEFT BLANK

# INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California